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1911.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 700 men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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ALLEN HAZEN,

President New England Water Works Association,

1911.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

GAS PRODUCER PUMPING PLANTS AT MANCHESTER, MASS.

BY RAYMOND C. ALLEN, ASSOCIATE MEMBER AMERICAN SOCIETY CIVIL ENGINEERS.

[*Read January 11, 1911.*]

The town of Manchester, or, as it is frequently called, Manchester-by-the-Sea, is a very pretty little town on the coast of Massachusetts Bay, between Beverly and Gloucester. It has a population of about 2 800, which is increased during three months by a large summer population to from 4 500 to 5 000.

The summer estates are held in comparatively large tracts, and landscape gardening is carried to a high state of development, requiring as a result an abnormally large amount of water.

The original water supply in Manchester was derived from driven wells in the village, and was installed in 1891 and 1892 under the direction of Mr. Percy M. Blake, and was designed to supply about 200 000 gal. per day as a maximum.

With the installation of the plant the town entered upon a period of very substantial growth along summer-resort lines, and the need of more water soon made itself felt.

This need was met from time to time, over a period of some twelve years, by the driving of more wells, and the town was very fortunate, in that the watershed of its plant was able to yield up to about 500 000 gal. per day. During the last ten years, however, it became very evident that further sources of supply must be obtained if the needs of the community were to be properly met.

Many propositions were discussed and none found satisfactory, until in 1907 the entire matter was placed in the hands of Mr.

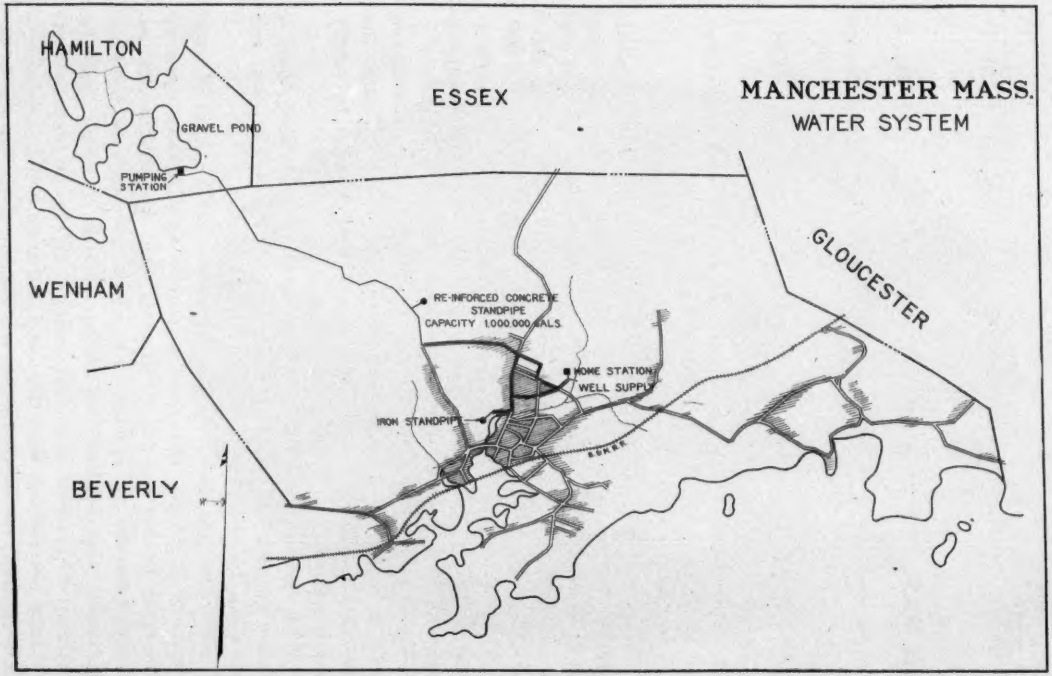
HAMILTON
ESSEX
MANCHESTER MASS.
WATER SYSTEM
GRAVEL POND
PUMPING STATION
WENHAM
GLOUCESTER
RE-INFORCED CONCRETE STANDPIPE
CAPACITY 1,000,000 GALS.
HOME STATION
WELL SUPPLY
IRON STANDPIPE
BEVERLY

FIG. 1.

Desmond FitzGerald, who, after a most painstaking and detailed study of the whole situation, recommended that the town secure the waters of Gravel and Round ponds, in the neighboring town of Hamilton, about three miles distant from the home pumping station.

This advice was adopted by the town and the supply obtained and developed. (Fig. 1.)

This development, of which the writer had charge, included the construction of about two miles of 14-in. and about one mile of 16-in. pipe line; the construction of a reinforced concrete reservoir 50 ft. in diameter and 72 ft. high, having a high-water line some 83 ft. higher than the old iron standpipe which failed to serve the higher hills of the town now in demand for building purposes, and the installation of new pumping machinery to raise the water to the new height.

The level of the high water in the new reservoir is 275 ft. above mean low water, that of the surface of Gravel Pond 50 ft.; and that of the floor of the home or old pumping station 22 ft. above the same level.

The total head, including friction for the Gravel Pond Station, amounts to 236 ft., and at the home station to 260 ft.

Owing to the fact that many years' experience had demonstrated that the flow of water from the driven wells at the home plant was limited to about 750 000 gal. in twenty-four hours, this was taken to be the size of the units to be installed there, and two one-million gallon units were decided upon for the Gravel Pond Plant.

At both stations it was decided to install units in duplicate.

The brake horse-power necessary per unit was determined to be 65 b.h.p. for the Gravel Pond Installation, and 50 b.h.p. for the home station.

Before obtaining bids, various pumping plants were studied to determine upon the method to be used. Steam pumps with from 90 000 000 to 100 000 000 ft.-lb. test duty were investigated; steam turbines direct connected to multistage centrifugal pumps; and oil and gasoline engines with power pumps, without satisfying ourselves that we had obtained that best suited to our needs.

The precedents and literature for the use of internal combustion

engines in pumping practice gave us but little upon which to base definite conclusions, and we were nearly ready to ask for bids on steam pumps when our attention was called to the use of producer gas.

Preliminary investigation interested us sufficiently to cause us to spend several weeks in travel and study of producer plants of about our horse-power in several of the eastern states. We visited such installations in numerous places and saw many and various types. The general efficiency obtained surprised us somewhat, and their reliability of operation did much to dispel many doubts in our minds. We saw these installations in factories where shut-downs meant expensive delay and financial loss, and found the owners generally pleased with the operation of their plants and that they were saving money over previous steam installations.

After careful investigation and study we determined to ask for proposals for suction gas producers, gas engines, and power pumps for the solution of our problem.

The next question arose as to whether we should ask for tenders for the complete plant, or whether we should ourselves determine the various component parts and install them. The first method had in its favor the element of undivided responsibility, and the guaranty of a specific duty for the complete plant; and had in its opposition the fact that we would have to pay a considerable sum for the superintendence and guaranty which, with the use of a little thought and study, we might save and spend to good advantage elsewhere.

The disadvantage of the second method was chiefly the matter of divided responsibility and the added detail study necessary for the engineer. Under this method we must also assume the responsibility of the efficiency of the combined plant, and see that each part of our equipment was of proper design and efficiency.

It was finally determined to adopt the latter method, and proposals were invited for two 50 h.p. and two 65 h.p. gas producers; two 50 b.h.p. and two 65 b.h.p. gas engines; two 750 000-gal. and two 1 000 000-gal. pumps. The specifications for this machinery were broad in their terms and stated the general problem to be solved. Producer makers were required to submit with their bids data as to the design and size of their equipment, especially in

relation to the grate area, scrubbing devices, and fuel efficiency guaranteed.

The engine bidders were required, among other items, to state their efficiency at varying loads, preferably in British thermal units per horse-power hour.

The following extract from the specifications will serve to explain the attitude taken by the writer: "It is the purpose of the Board of Water Commissioners to compare proposals upon the basis of cost plus the quality of design and workmanship of the apparatus proposed, and its fitness for the conditions of the town of Manchester, as judged by the said board."

Proposals were received from six manufacturers of gas producers, eight engine manufacturers, and four pump firms.

Two of the bids received for producers included engines in the price tendered. The others were as follows: $4 950; $6 965; $5 565; $5 720; and $5 000. The fuel to be used was pea and buckwheat-size anthracite, averaging about 12 500 B.t.u. The guaranties of efficiency ran from 75 per cent. to 80 per cent. of the heat of the coal in gas. The scrubbing arrangement in all but one type was that of coke or wooden slats and trays. The standover loss for a ten-hour run averaged about one pound coal per horse-power. The greatest difference was found in the grate areas, and the amount of coal to be gasified per square foot of grate surface. This some of the manufacturers claimed was entirely an arbitrary matter and of minor importance if the design of the producer was proper.

To the writer it seemed of the first importance and in deciding upon the producer to be used this factor was given important consideration by him. Data submitted showed some 50-h.p. producers with 3.7 and 4.9 sq. ft. area of grate and others of 7 sq. ft. for the same rating.

The smaller area means a greater amount of coal gasified per square foot of grate area with a hotter fire, more clinker, — the bane of the producer, — more frequent charging with consequent disturbance of the fire, and a more uneven gas.

The times to be charged during twenty-four hours varied from every three hours to ten hours.

The engine bids were all for four-cycle engines and varied from

single cylinder horizontal engines to four cylinder vertical types with weights running from 8 000 to 18 000 lb. for the 50 h.p. units.

Prices varied from $11 165 to $14 078 for two 50 h.p. and two 65 h.p., a total of 230 h.p.

The engine speed averaged very closely 270 r.p.m., all being very nearly that rate.

The fuel guarantees ran from 1.25 lb. of coal per h.p.-hr. to 10 000 effective B.t.u. per h.p.-hr. at full load.

Pump bids were on triple power pumps of both the double- and the single-acting types, and prices ranged from $6 115 to $9 590, with guarantees of from 78 per cent. to 85 per cent. efficiency.

The tabulation and study of the various bids and their many permutations and combinations gave the writer food for many hours' careful study and was indeed a difficult task. He was first concerned in selecting the units, which, from the data presented and from his observations, were best suited to the problem at hand. This after much balancing he determined only to find that he had selected nearly the most expensive combinations possible. Repeated attempts gave the same result and at length it was determined that of the proposals presented, those of the Smith Gas Power Company, of Lexington, Ohio, and that for the Nash Engine, by the National Meter Company, of New York, and that of the Goulds Manufacturing Company, of Seneca Falls, N. Y., were best suited to our needs, and the contracts were awarded to them.

The gas producers selected were of the kind termed Type B by the Smith Company. They operate on pea or buckwheat anthracite or on the semi-bituminous coals. The scrubbing device is a mechanical one occupying small space, situated on the gas line over the producer and consisting of two revolving enclosed baffle plates, belt driven, from the engine and running one within the other in opposite directions, at a speed of about 1 500 r.p.m. The gas passes upward through these plates and meets a spray of water in which it is literally washed and scrubbed, the impurities falling to a trap below and running thence to the drain.

This producer requires less room than the ordinary producer equipped with the tall tank scrubber of coke or wood and gives excellent results. The efficiency guaranteed was 75 per cent. to

FIG. 1.

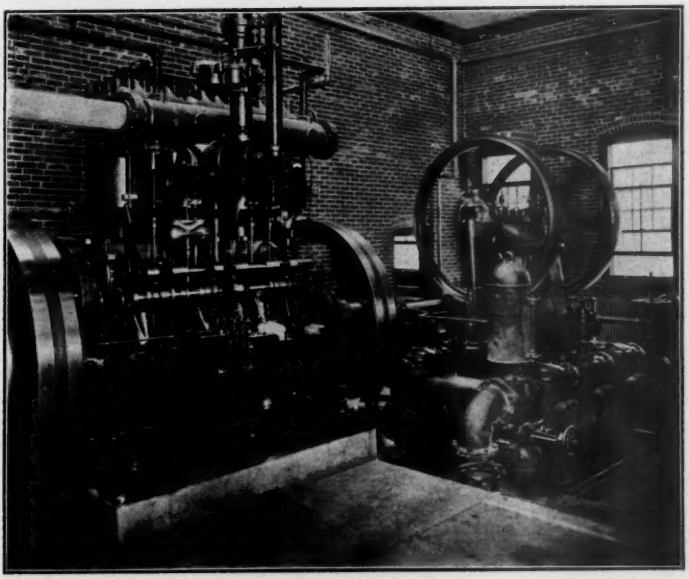

FIG. 2.
VIEWS OF ENGINE AND PUMP.

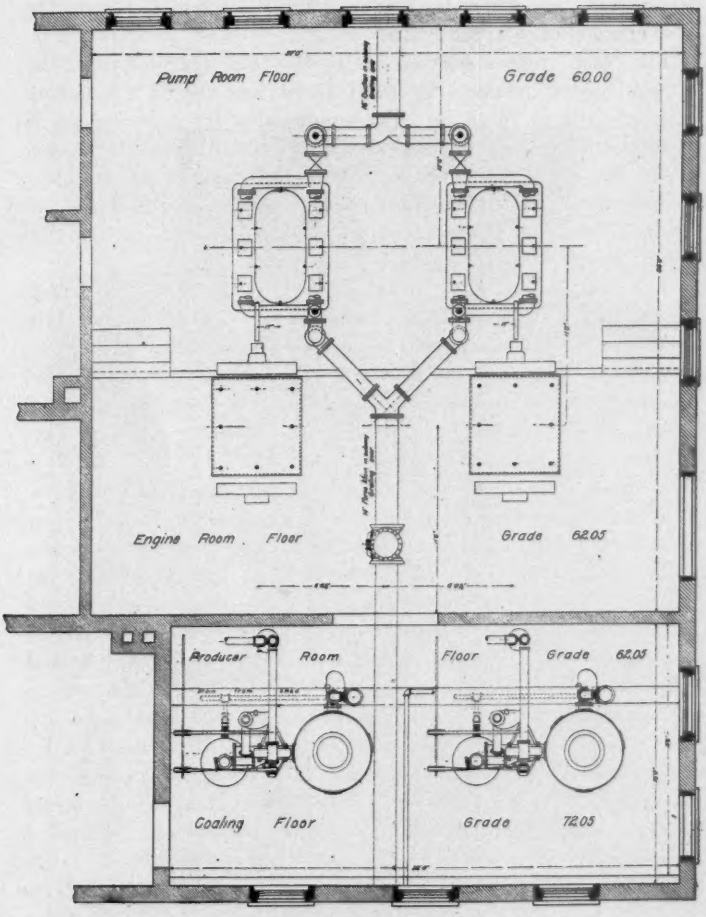
Pump Room Floor
Grade 60.00
Engine Room Floor
Grade 62.05
Producer Room Floor
Grade 62.05
Coaling Floor
Grade 72.05
TOWN OF MANCHESTER
PUMPING STATION, GRAVEL POND
MACHINERY LAYOUT

FIG. 2.

80 per cent., and gas at the engine of 120 B.t.u. and 80 ft. per h.p. It is charged once in ten hours.

The Nash engines selected are of the three-cylinder type, the 50 h.p. having cylinders 9½ in. by 11 in., and the 65 h.p. having cylinders 10½ in. by 14 in. The compression for producer gas is about 160 lb. These engines were guaranteed to give their rated b.h.p. on 10 500 B.t.u. per h.p.-hr. at full load, 11 500 B.t.u. at three-fourths load, 13 500 B.t.u. at one-half load, and 23 000 B.t.u. at one-fourth load. Their speed is 260 r.p.m. for the 65 and 300 r.p.m. for the 50-h.p. engines.

The pumps are 8 in. by 10 in. and 9 in. by 12 in. double acting, for the 750 000-gal. and the 1 000 000-gal. respectively and are guaranteed as having an efficiency of 85 per cent.

A new brick station (Fig. 2) was designed by the writer at Gravel Pond for the two million-gallon units, and the machinery installed in the spring of 1909. The pipe lines and concrete standpipe having already been erected, the new plant was put in commission in June, 1909. About the first of August of the same year, the operatives having learned to operate the new plant, the home station was dismantled and the old steam pumps removed, and work was started upon the new equipment there. This was done at the height of our summer season, and that the faith we reposed in the new plant was not misplaced is evidenced by the fact that the entire season's work was carried through by this plant without any serious trouble whatever.

At the end of the succeeding November, the home plant was set in operation, and both have been in constant use since.

The operatives who run these plants are both old steam engineers and approached the work with some doubt and misgivings, having a large share of the feeling that while theoretically, perhaps, a horse-power is a horse-power, still that generated by steam is the most reliable. Their experience in learning the operation of the plants was without particular incident or difficulty, and as they became familiar with the new work and their interest increased, their efficiency kept pace with it, until they seem to have as much confidence in their plants as if their old friend steam was still working for them.

The producer consists essentially of an upright iron cylinder

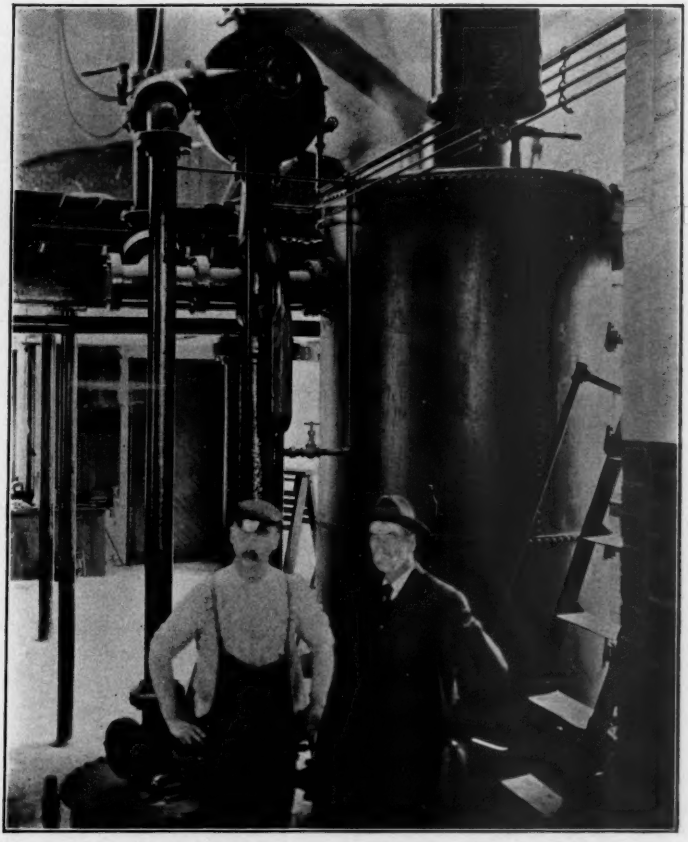

FIG. 1.
VIEW OF PRODUCER AND SCRUBBER.

10 ft. high and 5 ft. in diameter, lined with suitable fire brick, into which coal is fed from the top. It is kept filled with coal for almost the entire depth, the space occupied by the bed of fire being quite thin.

The operator, commencing his work with the fire standing over, cleans his fire by means of poking bars which are passed vertically down from the top of the producer through small protected holes, close to the lining, working the fire ash to the grate. The fire is shaken by a swinging grate, and the ash and clinker removed from the lower doors.

Upon the skill of the operator in cleaning and coaling his fire rests in a great measure the best results as to economy and even running. It is not a difficult matter to learn, but its practice calls for constant and conscientious observance, if the best results are to be had.

The fire cleaned, the coal for the day's run is placed in the producers. This is fed from the top, and we have arranged our plants in such a manner that coal is stored at the level of the producer top and from thence wheeled directly to the producer.

The producer having been charged with coal, a pipe to the atmosphere is opened and a draft from below forced through the producer, starting up the fire, and in from five to fifteen minutes producing a gas whose quality is tested from time to time by lighting a burner attached to the line. When the flame burns at the right color for good gas the operator is ready to start his engine.

Shutting off his blower, which we run from a water motor, and closing the "standover pipe," the engine is started by turning it over by compressed air introduced into one cylinder. With the engine in motion from this agency, the other two cylinders draw in gas from the producer and commence their explosions. When these are occurring regularly the air is cut off from the other cylinder and gas admitted.

Current for ignition is furnished by storage batteries for starting and for regular running by a belt-driven magneto floating its excess on the storage cells.

The air for starting is compressed by an air-compressor belt-driven from a shaft operated from the engine. Another air com-

pressor is belt-connected with the water motor which is used to operate the power blower. This second air compressor and water motor we installed after being left without compressed air and both engines at rest.

The engines and producers are in duplicate and so arranged that either engine may be used with either producer.

With the engine running smoothly, the pump is put in by throwing in a friction clutch starting the pump with the by-pass open. The by-pass is slowly closed and the load is gradually picked up with the minimum of shock.

In shutting down it is the custom of our operatives to shut off the gas from the engine and let the whole plant come to rest gradually. By this means there is no perceptible water hammer; but if the clutch were to be pulled out suddenly, a very severe water hammer would result.

Pumping can be quietly and easily stopped and started at any time with the engine and pumps running by opening or closing the by-pass gradually.

The time necessary for starting from the fire left on the night before varies from thirty minutes to an hour in our experience, depending upon whether or not the operator has a helper in cleaning the fire. In an emergency the plant can be started without cleaning the fires, as soon as the blower can warm up the fire sufficiently to give good gas, or, under reasonably good conditions, in ten to fifteen minutes. From an empty producer I am not able to state how quickly the engine can be running, but we have accomplished it in about two and one-half hours.

The results of operation have been very satisfactory and fulfilled the guaranties given us for test conditions by the makers.

Test conditions have given us at the home plant, a pumping duty of 150 000 000 ft. lb. per 100 lb. of coal; or, allowing 85 per cent. efficiency for the pumps and a proper allowance for power for the scrubber, air pumps, etc., a consumption of 1.002 lb. of coal per h.p.-hr., including standover. At this plant we have a load of about 90 per cent. of our rating.

At the Gravel Pond Station, we have a load of but a trifle over three quarters of our rating, and a lower duty is naturally to be looked for.

Under test conditions at this plant under three-fourths load, we have obtained a pumping duty of 125 000 000; or, with the same allowance for efficiency of pump and shafting, a coal consumption of about 1.2 lb. of coal. Under a load of its rated capacity and a ten-hour run, the above results correspond to about 150 000 000 duty, and just about a pound of coal per b.h.p.-hr. for the engine and producer duty.

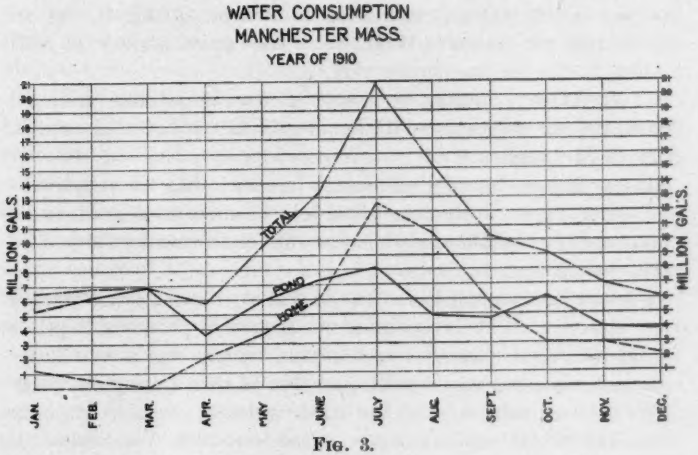

FIG. 3.

We draw our water from two sources and run both plants throughout the year mixing the water. (Fig. 3 shows the consumption for 1910.)

The home plant has its hardest work in the summer when the load is greatest and the cold ground water is desired, making long runs at nearly its full capacity.

The Gravel Pond Plant, on the other hand, runs more nearly uniformly, pumping about eight hours a day in the summer and five or six hours a day in the winter, and at two thirds its rating.

Under these conditions, the home plant gave for the summer months a pumping duty, including standover, from 104 000 000 to 135 000 000 ft. lb., averaging about 120 000 000 ft. lb. per 100 lb. of fuel.

During other months, when the plant is run but two or three days per week, and about five or six hours per day, and stands over the balance of the time, our duties including all standovers will average about 75 000 000 for a two-day run a week.

The results at the Gravel Pond Station, having due regard to the fact that the plant is run fewer hours per day and at a lower ratio to its capacity, are quite as good as those at the home station.

From January, 1910, to January 1, 1911, the home station pumped 50 880 000 gal. against a total head of 260 ft., at an expenditure of coal of 131 609 lb. This gives a duty of 83.3 million ft. lb. for the entire year.

At the Pond Station we have in the same time pumped 66 580,000 gal. at an expenditure of 175 479 lb. of coal or at a duty of 73.4 million ft. lb.

These figures, I would emphasize, are including all standovers and items of every sort, and include four to seven months when the plants are run but about six hours a day for but two or three days each week.

I would further emphasize the fact that, remembering what I have stated, that the economical running of a producer depends on the skill of the operator in handling his fire, the above duties represent the combined handling of several men during the year.

We are well satisfied with the result when we are able to pump some 118 000 000 gal. of water against a mean total head of 246 ft. with a total coal bill of 153½ tons.

Our installations are for a total of 230 h.p. and cost us above the foundations, exclusive of pumps, $22 000, or a little less than $96 per b.h.p.

Including the pumps, the cost for the total equipment on foundation was about $32 000.

The experience of the department at Manchester is that all the operators who have run these two plants have learned their work readily and had no special difficulty in operating.

It has also shown, —

1. A cool, clean, uniform fire must be maintained in the producer, and, to obtain this, operators must learn from experience how to care for and maintain their fires and be persistent in so doing.

2. The operator must keep the engine clean and well oiled, and the ignition and compression in perfect order.

3. For the best economy the plants should be run at least ten hours per day, as a long standover and consequent cleaning and longer blowing up, use coal to no purpose.

4. That under the best conditions a station duty at full load of 150 000 000 ft. lb. per 100 lb. of coal can be obtained; and that a station duty for the summer months of 125 000 000 and for the year, including about six months when runs of but two or three days of six hours each are made, of about 80 000 000, can be obtained.

5. That our fuel cost with coal at $5 varies, for 1 000 000 gal. raised one foot, from an average of 1.73 cents in summer to 2.78 cents in the short runs and long standovers of winter; and, even when taken for the year and under the adverse conditions mentioned, the average for the year is 2.5 cents.

These are a few of the results which we have found at Manchester in the course of a year and a half of constant use, and we feel that they show good economy. The operation of the plant has not been at all difficult and the repairs very slight.

The writer feels that, for conditions of water-supply pumping similar to those at Manchester, the use of gas engines operating from suction producers is worthy of careful consideration, not particularly as to first cost, but to economy of operation. Were we at Manchester to install a new plant to-day, I am of the opinion that it would be of the type I have described to you.

DISCUSSION.

MR. FRANK L. FULLER.* I would like to ask Mr. Allen how nearly the Venturi meters agree with the pump displacement?

MR. ALLEN. When the pumps were first installed they had a slip of about one per cent. At the present time it is a little less than two per cent. The pumps have not been packed since they were put in.

MR. JOHN C. CHASE.† I would like to ask how near the service meters correspond with the meters on the suction?

* Civil Engineer, Boston, Mass.

† Consulting Engineer, Derry Village, N. H.

MR. ALLEN. I am working on that at the present time, but haven't any results to give yet. I am interested to see how it will come out.

MR. HARRY L. THOMAS.* Mr. Allen is to be congratulated upon the fact that the operators have had so little trouble in managing the plant. We do not have any trouble now, but the paper which I presented two years ago † dealt particularly with the drawbacks in connection with such an installation. I might say that we have now conquered our difficulties and are entirely satisfied with the results that we are getting from our plant, so much so that we are in process of installing another plant, which will consist of a 2 million gallon pump with a 100 h.p. producer and an 85 h.p. gas engine. It is of a different make from our first plant, although of the suction type. We are getting, running as we now are, a duty of 90 million, and last October, when we were operating under conditions similar to those that obtained during the test of our plant in 1906, we developed 124 million. The duty during the test exceeded 140 million; I think it was between 140 and 142 million.

There are a few questions I would like to ask Mr. Allen. One is in regard to the exhaust pipe from the engine. At first we piped into a cast-iron muffler, and then from this muffler out through the roof of the building. Now we have run the pipe into a concrete pit, which is situated perhaps 90 feet from the building, and from that we lead a pipe into a dry well. We did this for the purpose of doing away with the noise of the exhaust, but we didn't provide for any expansion of the exhaust pipe, with the result that an elbow near the engine, at the free end of the pipe, simply went to pieces. I wonder just how Mr. Allen has provided for expansion, if he has similar conditions.

Another matter is about the chimney pipe from the generator, — whether it runs independently through the roof, or whether Mr. Allen considered running it into the chimney flue of the station.

MR. ALLEN. In relation to the exhausts, we pipe them up through the roof and use no muffler. One of our plants is near the pond, in the wilderness, and it doesn't bother anybody. The

* Assistant Superintendent, Hingham Water Company, Hingham, Mass.
† JOURNAL N. E. W. W. A., Vol. XXII, p. 1.

other one is down in the village, but no one seems to notice it very much. We have three cylinder engines and they do not make nearly as much noise as the average automobile with the muffler cut out. The nearest house is about 100 yards away, and the neighborhood is thickly settled, but we don't hear any complaint about the noise. I think Mr. Thomas has a one cylinder engine and the exhaust comes at longer intervals, and so, perhaps, it makes more of an impression on anybody who is listening.

As to our standover pipes, I had intended to put them into the chimney, but after I had considered it and gotten advice I concluded I wouldn't, and piped them straight up through the roof. I think the straighter and freer one of these standover pipes can go, the better. I was also afraid that if I put them into the chimney I might get a collection of gas there, and some day somebody might come along with a stove and put the pipe in the chimney and we would have an explosion. I think it is a good idea to have the pipes go as directly to the air as possible.

MR. THOMAS. How about coal? What luck are you having in purchasing a uniform quality?

MR. ALLEN. We are buying pea anthracite. I don't know just what the name of it is, but I am advised it has a thermal value of about 12 000 B.t.u. We are getting it for $5 a short ton delivered, and it runs pretty uniformly. We have had no trouble with sulphur, we have had very few back fires, and it gives quite a uniform gas. I am not familiar with the mine from which it comes, but it is the ordinary screening. We get it from a local dealer who screens his anthracite as it comes in. If we bought from the mines, we would have to buy in too large a quantity for our needs.

MR. THOMAS. At present we are using the Scranton Coal Company's pea coal. While we have had all sorts of difficulty in determining what was the best coal to use, and where to get it, we have finally settled upon this particular coal, which is giving us excellent results. We are pumping a million and a quarter gallons a day and burning from 1 050 to 1 080 pounds of coal. That is against 70 pounds pressure. We don't burn much less if we only pump against 40 pounds. There is greater economy in

pumping against a heavier pressure. Our coal is costing us, landed at the pumping station, $5.30 a long ton.

MR. HAYES.* I should like to ask Mr. Allen whether the working platform around the generator is wood or iron.

MR. ALLEN. Iron.

MR. FULLER. I should like to ask Mr. Allen how much noise this plant makes in the building.

MR. ALLEN. The 65 h.p. plant makes considerable noise in the building. The 50 h.p. plant makes a great deal less, whether because it is a smaller size or not I don't know. I think it is chiefly because there is a little more care taken in the timing gears. The pump gears have rawhide pinions and the noise from it is slight. The chief noise from the engine is from the cam shaft and the valve rods going up and down. One plant is quite noisy and the other quite comfortable, I should say.

* Of F. H. Hayes Machinery Company, Boston.

THE RELATION OF FLIES TO THE TRANSMISSION OF INFECTIOUS DISEASES.

BY HERBERT D. PEASE, SANITARY EXPERT, BOARD OF WATER SUPPLY, NEW YORK CITY.

[*Read September 22, 1910.*]

In the history of the development of sanitary science, as in the progress of all subjects where the natural sciences play a part, we find that the practical results have been those that have been sought for primarily. Thus, in the prevention of the spread of infectious diseases, those in which a method of transmission was discovered early have been the ones to which the greatest preventive efforts have been applied. In the case of typhoid fever, the early discovery of its relation to polluted water was the means of stimulating the development of the great engineering work which has made it possible to eliminate water-born typhoid.

We have come to a point where a large part of the value of the engineering aspects of this work have been demonstrated, and still we find what we are pleased to call "residual" typhoid fever. The cause of residual typhoid fever is a matter of the very greatest importance, not only to the sanitarian and to the epidemiologist, but also to those who are working in sanitary engineering, and even to those who are working in the special field of water purification. Because, if we are to get the greatest efficiency from the water purification works, we must decrease the amount of pollution having access to them, and that means that we must cut down the amount of typhoid fever caused by agencies other than by water.

If you have studied the occurrence of typhoid fever during the various seasons of the year in various parts of the world, you will find, in practically all civilized countries, that typhoid not only exists, but that there is what we call the "autumnal increase," or a special seasonal prevalence, of the disease. This has its height anywhere from July to October, varying in different parts of the world. This autumnal increase, in the opinion of many epidemiologists, has comparatively little to do with water transmission

of infection. For several years I have been looking for a first-class epidemic of typhoid fever in the late summer and early fall, which could be really fairly attributable to water transmission, and I may say that I know of none except those in which the pollution of the water has occurred almost immediately before its consumption. If the pollution has been a direct one, I think it is possible to have even typhoid bacilli carried by water in the summer time and in the early fall, but we have yet to find any outbreaks due to indirect water pollution in the summer season.

If we take, for example, the city of Albany, we will find that its maximum incidence of typhoid fever during the years when it was consuming raw Hudson River water occurred in the winter season, and yet the autumnal increase of the disease was also noted in the months of August, September, and October. Not long ago the filter plant of the city of Poughkeepsie was in bad condition. There was at about the same time a tremendous increase in the amount of typhoid fever in that city. This was in the winter season, but the autumnal increase in typhoid likewise existed. As soon as the filter plant in Albany was installed, the winter typhoid fever practically disappeared, but there was still the autumnal increase. In the city of Poughkeepsie the same thing was true. When the filtration system was put in good condition, the winter typhoid practically disappeared, but the autumnal increase was still present; and in the case of Poughkeepsie it was even greater than it had been before the filter was repaired and put in proper condition.

Now, what is the cause of the autumnal increase in typhoid fever? I do not really think any of us can satisfactorily answer that question. There are many factors to which have been attributed the cause in part, or in large part, — namely, milk, fresh vegetables, foods, shellfish, and contact cases. I think most medical epidemiologists believe that direct contact between cases, convalescents, and carrier cases, is the cause of a large part of the autumnal increase in the disease, especially in cities. The contact due to the migration from the cities to the country and back again in those months undoubtedly has something to do with it, but yet, unquestionably, flies play a considerable rôle in this increase.

Many epidemiologists believe that the flies are the means of

transmitting disease in the rural districts rather more than in the cities. Doubtless that is the case and that in the rural districts disease is much more frequently transmitted by the flies than in the cities. They argue that the opportunities for the fly to come in contact with infectious materials are not as great in the cities as in the country districts, and undoubtedly that is the case. D. D. Jackson, on the other hand, feels certain that flies are responsible for much of the summer typhoid and infant mortality in New York City, through the transmission of sewage bacteria from the water front. While some may doubt that the flies came in contact with the infectious material from the sewage left upon the pillars at the wharves and the piles and the wharves themselves by reason of the lowering of the tide, as was claimed by Jackson, there can be no doubt that the unsanitary conditions which exist around the piers in the city of New York, and in those very congested districts of the city near the piers, furnish ample opportunities for flies to become infected.

I shall speak a little later of the outbreaks of typhoid fever which have been caused by flies, and during which flies caught in the neighborhood of the cases where unsanitary conditions existed, were found to contain typhoid fever bacilli both on their legs and in their fecal discharges.

To speak more particularly about the fly, we will do well to note first that there are a great many varieties of flies, and undoubtedly many of them are of importance in this matter. It will not be possible to give a detailed description of the different types of flies, and why some of them are probably more important than others in the transmission of typhoid fever, but it will suffice to say that the fly which breeds upon organic matter of animal origin is probably much more important than the fly that breeds particularly upon decaying vegetable matter. Now, as a matter of fact, the ordinary house fly, the *Musca domestica*, which constitutes about 90 per cent. of the flies which are found in our houses and around habitations, does not breed in decaying animal matter. The female *domestica* lays its eggs chiefly in decaying vegetable matter, and apparently the only animal matter in which it will lay its eggs is human excrement. Some biologists even doubt that the *domestica* frequently lays its eggs in human excre-

ment. So the general statement the the *domestica* is responsible for most of the transmission of typhoid fever may be questioned by those who have observed that this species of fly does not lay its eggs frequently in animal matter.

There are, however, a large number of other flies, which, if we didn't stop to examine them, we would classify as the *domestica*, which are frequently present in civilized communities. There are the very small fruit flies which breed only in decaying fruit. Then there are the large flower flies which breed particularly among flowers and vegetation. Then we have, as you all know, the biting flies that develop in stables, and there are also the blue-green and so-called "blow" flies that develop particularly upon decaying animal matter. These flies are not seen frequently in human habitations.

So we see that the species of fly and the method of breeding are matters of very considerable importance. The fly ordinarily lays its eggs in such a location as will furnish the best food for the development of the egg and for the nourishment of the larvæ. It is astonishing that so little is known about the course of development and life cycle of many of these species of flies other than the *domestica*. The *domestica* has been studied rather thoroughly, and most of the information which is to be had in literature concerns this particular species.

The female *domestica*, as I have said, lays its eggs in decaying vegetable matter and in human feces. It will lay at one time about fifty eggs, and these, depending upon the temperature, the amount of moisture present, and other physical conditions, will develop into the larval stage in from eight to twenty-four hours. The question of temperature is one of considerable importance in the matter of the life cycle of the *domestica*, and the question of moisture also determines its rate of growth.

The *domestica* will lay from one hundred and twenty to two hundred eggs in one season. Sometimes they pass through even as many as twelve generations in a season's cycle, all depending upon the temperature and the water and food supplies.

These eggs, fortunately for us, have a great many enemies. The various ants carry off a great many, as well as predatory flies of other species, for use as food. In many places the eggs and the

PHOTOGRAPHS OF SECTIONS OF FLY PEST MOVING PICTURE FILM.

Flies on a piece of meat.

Eggs of fly.

Larvæ hatched from eggs.

Larva molting.

Larvæ penetrating into earth to begin pupal existence.

Pupæ.

Wingless insect emerging from pupal stage in earth.

larvæ, or the maggots, as we commonly call them, are now grown artificially for the purpose of feeding high-grade and fancy fowl and birds.

The larval stage of the *domestica* is really its most important stage, from the standpoint of the growth of the fly, for it is during this stage that the fly reaches its full size. The fly, when it reaches the winged state, has already attained its full development. During the larval state, it molts, that is, it sheds its skin and grows to a larger size and again casts off its shell. This it will do twice during the course of the five days that it exists in this larval state.

During this stage it is possible to find large numbers of them in various decaying vegetable and excrementary material. They have been found as many as five hundred larvæ in one human excrement. The numbers that have been found in a pound of horse manure run up into the thousands. Various investigators have taken considerable pleasure in endeavoring to find a larger number than some other investigator.

From the larvæ stage, the fly passes into what is known as the pupal stage. During this period, the larvæ burrow into the earth, sometimes as far as five or six inches, and develop hard shells and there pass through another stage of their life cycle. At this time the insect is practically in a hibernating condition. This is a matter of considerable importance from the standpoint of the transmission of disease, for if typhoid feces should be thrown upon or buried in the soil, and were not put further down than six inches, it would be quite possible for fly larvæ to penetrate that distance into the soil, and take into their digestive tracts considerable amounts of this fecal material. When these larvæ developed into winged insects, they would discharge this same material and thereby distribute actual germs of diseases. If typhoid feces, for example, are placed in a dry earth closet where it is customary merely to cover the surface with a film of earth, it is quite possible for the larvæ to burrow under or into such material and become contaminated by actually eating the filth under the soil, and then coming out again in the state of the winged fly and transmitting the germs by means of their excrement.

Flies can hibernate in warm places during the winter time, not only in the pupal stage, but they can also do so in the form of the

winged insect itself; and one investigator, who seemed to be interested in the mathematics of the subject, found that in the spring forty thousand flies developed from twelve which had been hibernating in a warm place during the winter.

One of the most important phases of the relation of flies to the transmission of diseases is the question of the flight of the fly. But how far do flies usually go? When he does travel, he can make about ten miles an hour. Many say that flies never pass more than two hundred feet away from the place where they come out of the pupal stage into the winged state. But, as matter of fact, flies have been found many, many miles from the site of their full development. Some years ago I was familiar with a legal controversy between certain of the fish-oil companies and the Public Health and Marine-Hospital Service, over the location of a hospital near one of the company's factories. The testimony of the witnesses for the government went to prove that large numbers of the flies were found frequently far out at sea on steamboats and they were identified as coming from this region, where they bred and grew to maturity on the exposed drying fish refuse. It is therefore undoubtedly the case that flies can be blown, as mosquitoes can be blown, long distances. Ordinarily, the fly, probably, does not pass more than three hundred or four hundred feet away from the place where it originally developed into the winged insect; but that it can go a very much longer distance is undoubtedly true. In the latter case, the germs which they may take up into their digestive tract, and which they may carry in a virulent condition for periods of two to three weeks on the surface of the body, mixed in with the hairs and mucilaginous material which is on the pads of their feet, can be carried over long distances.

The fly not only breeds in decaying vegetable and animal matter, but it actually uses those materials as the source of its food. As I have already said, the larvæ take infectious matter into the digestive tract during that stage of their existence, and the winged insect will also do the same. Of course, as you know, the fly in feeding first liquefies the solid materials with its own secretions, and then absorbs the dissolved materials into its digestive tract.

The really important work in connection with the demonstration of flies as transmitters of disease was done in the early days of

bacteriology. In the Hamburg outbreak of Asiatic cholera, it was shown that flies were capable of taking the cholera bacteria into the digestive tract, and of giving them off in considerable numbers in the fly-specks or excrement, for periods up to two weeks. The living bacteria were also to be found on the surface of the fly during similar periods. Later on, this was shown to be the case with the typhoid bacillus, and we now know that the fly can take into its digestive tract living typhoid bacilli and continue to give them off for periods of from one to three weeks, and that the living typhoid bacillus can be found upon the legs and hairy body of the fly for somewhat similar periods.

One of the most interesting results of studies concerning the relation of flies to the transmission of disease has come from the work of Lord and others upon the association of the tubercle bacillus and the fly. Not only has it been shown that the fly harbors the tubercle bacillus as he does the typhoid bacillus, but it almost appears that there is an increase in the tubercle bacilli in the intestinal contents of the fly, when the fly has been fed upon tuberculous sputum. When we ponder over the fact that on the average one fly may deposit as many as fifty fly-specks during twenty-four hours, and that these fly-specks, when they are deposited upon food, may actually serve as a means for the introduction of living, virulent germs of disease into the human body, the importance of the fly problem becomes clearly evident. When the fly-specks are deposited upon substances such as furniture, wood, and cloth, they probably are without any significance from the sanitary standpoint, because the fly-speck naturally adheres to the surface of the material upon which it is laid and is not easily removed, and the effect of sunlight and air very soon kill off most of the varieties of the disease-producing organisms which it may contain. But where the fly has actually direct access to foods which are soon eaten without cooking, there is a direct means of introduction into the human system of the organisms which the fly has taken into its own digestive tract, or which it may have upon its legs and body.

It has been noted by Tooth and others that the fly seems to have a special predeliction for alighting on persons with typhoid fever. It is recorded by him that in the wards of a hospital flies

seemed to prefer to feed upon the skin and lips of the cases of typhoid rather than upon the cases of sunstroke and other diseases. Possibly this was due to the fact that the fly must of necessity have a certain amount of liquid diet in order to subsist, and in many rooms the only moist articles are the human beings, and naturally the flies are attracted by the perspiration of the people who are inhabiting these rooms.

One interesting item has been reported by Veniger. In the city of Vienna, there occurred a case of smallpox in a house not otherwise infected with this disease, but which was in close proximity to the smallpox hospital. A little child developed a localized smallpox infection upon the face. Those of you who are familiar with the clinical manifestations of smallpox know that it rarely occurs under natural conditions of infection except as a generalized disease. This child, however, had a localized smallpox infection on the face similar to the results of smallpox inoculation as formerly practiced, and the most plausible reason for the development of this localized smallpox seemed to be the possibility that a biting fly had come from the smallpox hospital, where it had fed upon the skin of the cases there and had introduced the virus into this spot on the face of this child..

Historically the fly is really of considerable interest. Those of you who care to do so can find many of the modern ideas on the transmission of disease and their prevention in the books of Leviticus and Deuteronomy in the Bible. Reading them in the light of modern knowledge, you will find very interesting revelations. I have no doubt that many of the customs of incense burning and fumigating in the Hebrew temples, and religious rites of that nature, were to a large extent hygienic measures. We know from a study of some of the other rites which were observed by the ancient Hebrews that their main practical object was the prevention of the spread of disease. For example, one of the interesting things which has been studied out is that the ancient Hebrews, as part of their religious offerings, burned those fatty parts of the cattle which were most likely to be infected with tuberculosis. It is undoubtedly true also that in many of the rites, such as the burnt-offering and the burning of incense, vapors were produced which would either kill or drive away flies. As you all know, the

temples where these rites were performed were practically the slaughter houses and the butcher shops of the Hebrew people, and it is inconceivable that flies of some sort were not pests under such conditions.

I will not go over all the ancient references to flies in connection with disease, but Sydenham, who was probably one of the greatest medical observers, said in 1666, "If flies are plentiful in summer, autumn is likely to be unhealthy."

The Bishop of Kund in the fifteenth century endeavored to foretell the outbreak of plague by the changes in the weather and the prevalence of flies.

Coming to the more practical application of the subject, it is certain that many of the cases of typhoid fever which have occurred in the modern wars have been due to flies. That much of the typhoid fever among the troops engaged in the Franco-Prussian War was due to flies is generally believed. It has certainly been demonstrated that in our own Spanish-American War a very large part, at least ninety per cent., of the typhoid fever was caused by fly transmission, and eighty per cent. of all the deaths from all causes were from typhoid fever. In the army camps, the germicides, such as lime, placed in the latrines and the sinks, for disinfecting purposes, were found upon the food in the camp kitchen in the form of fly-tracks. Then again, with the onset of cold weather, the amount of the disease diminished very greatly. In the Boer War, during which there were 6 000 cases of typhoid and only 7 500 killed in all the engagements, when the cold weather came on the typhoid rate decreased; and when also successful efforts were directed toward the suppression of the fly, the disease was likewise very greatly reduced.

I have already spoken of the work of D. D. Jackson for the Merchants Association of New York City, and I expressed the opinion that the incidence of typhoid fever near the water front in New York City was quite possibly attributable to the action of flies in transmitting infectious material from the unsanitary conditions in those neighborhoods, and possibly also to some extent from the transmission of organisms from the sewage-covered rocks and piles. Personally, I am confident that much of New York City's autumnal typhoid is due to the activity of flies.

One of the most definite outbreaks of typhoid fever attributable to flies was described by Dr. Alice Hamilton, and occurred in Chicago in 1902. It was found that certain regions inhabited by foreigners were showing a very considerable number of cases of typhoid fever. A sanitary survey of the location was made, and very unsanitary conditions were found. Open privies were common, and so were flies. Some of the latter were collected, and, out of 18 flies, 5 were found to contain typhoid bacilli both in their fecal discharges and upon the surface of their bodies. The distribution of the typhoid cases and all of the factors were in harmony with the conception that the outbreak was due to fly transmission.

Prof. E. O. Jordan, of the University of Chicago, showed very conclusively that the outbreak in Winnipeg, in 1904, of typhoid was due to fly transmission. There very unsanitary conditions existed, and the fly existed likewise in enormous numbers.

During my connection with the State Department of Health in Albany, I investigated an outbreak of typhoid fever in the village of Castleton, about eight miles below Albany on the Hudson River. A case of typhoid had existed in June on the second floor of a house near the river, below the main drainage line of the village. In so far as I could determine, the discharges in that case had been thrown out of the second story window into the adjoining yard. There were no water or sewerage systems in this village. The cases, about fifty or sixty in number, which had developed between June and September, all had their onset among people who had been living within a block and a half of that particular house. The patients belonged to all classes of society. Contact of a direct kind was out of the question as a cause of the outbreak. The cases were distributed among the customers of many milk dealers. In fact, all of the evidence pointed to the conclusion that this was a fly epidemic. No flies were caught and examined for typhoid bacilli, but doubtless the latter were there.

If the typhoid bacillus is transmitted by flies, undoubtedly many other organisms capable of producing certain diseases, like diarrheas, are likewise transmitted. In India especial attention has been paid to this aspect of the subject, and Arnsworth, Al-

dridge, and Snell, of the British Army, and a number of other men, have written exhaustive articles, accompanied by very elaborate charts, all showing the relation between flies and diarrheal diseases in that country. Dr. Jackson's work for New York City is quite conclusive on this point.

There are certain remedies for the fly pest which I will speak of very briefly. Of course, the first to suggest itself is to abolish the breeding places. To do so is a matter of general sanitation. Any decaying or decomposing vegetable or animal substance of any form, even decaying and molding newspapers, furnish good media for one or another species of fly in which to lay its eggs, and for the development of the larvæ. The employment of general sanitary measures proper for thickly settled communities, and even of country districts, will wipe out to a large extent the breeding places of many species of flies. But the manure piles are chiefly at fault, in so far as the ordinary house fly or the *domestica* is concerned. Removal of such accumulations to regions farther than three or four hundred feet from habitations is one of the most effective and probably the most practical method of eliminating these breeding places of flies. In many of our large cities where the horse is gradually disappearing flies are likewise gradually disappearing.

Where it is impossible to remove the manure as frequently as once in every five or six days, which is the time necessary for the fly to pass through its entire life cycle to winged insect stage, there are other means that may be taken; but they are very inefficient in comparison with the actual removal of the manure.

For example, the winged insect will not go into a dark place to lay its eggs; it hardly ever penetrates beyond a short distance away from the light; so that the screening and darkening of manure pits is a more or less satisfactory method of treating these places. The application of disinfectants to manure for the purpose of killing the larva has been a subject of considerable experimentation, and some few satisfactory results have been obtained; but likewise a great many not so satisfactory have been obtained. It should be said, therefore, that attempts to disinfect manure heaps and pits for the elimination of the fly eggs, larva, and pupa are not to be recommended if removal is possible.

After the flies are with us, we can endeavor to keep them away from our surroundings by means of screens and various methods of exclusion, or by catching them with the numerous kinds of sticky fly paper or with the newer mechanical devices. The most efficient of these have as the principle of their operation some well-known biological phenomena. Flies, as I have said, all seek the light, and if you darken all the windows by means of blinds and curtains, leaving one light, you will find most of the flies at that spot. Fly traps on windows and wire cages illuminated at night with phosphorescent paint or the use of poisoned fly foods and drinks and sticky sweets all have biological reasons for their popularity. It is astonishing what results have been obtained in the catching of flies by simple and yet thoroughly scientific devices.

OF WHAT THICKNESS SHALL WE MAKE THE WALLS OF OUR LARGE PIPE LINES?

BY ALLEN HAZEN, CIVIL ENGINEER.

[*Read November 9, 1910.*]

(1) Cast-iron pipe is commonly designed with an apparently much larger factor of safety than is used in the design of steel pipe. Notwithstanding this, cast-iron pipe frequently breaks in service, while steel pipe practically never breaks. Why is the steel pipe more reliable in this respect than cast-iron pipe?

(2) The president of a water board asked me, some years ago, after a very uncomfortable experience, how it was that pipes which had been tested in the foundry by a careful inspector, to a pressure of 300 lb., break in service under a working pressure of less than 100 lb.

(3) The formulas that we most commonly use in computing the strength of cast-iron pipe assume an ultimate tensile strength of only 16 000 to 18 000 lb. per square inch, with a factor of safety of 5, while it is well known that the castings turned out by pipe foundries at the present time considerably exceed this strength. Why is it not safe to reduce the thickness of the pipe walls in inverse ratio to the increased tensile strength of the iron?

These are questions which have come up for discussion in our office frequently in the last few years. In considering them I have frequently had the benefit of advice from Mr. Emil Kuichling, and I wish to acknowledge at once many of his suggestions in that which follows.

I propose to take up these questions to-day from the standpoint of all the forces that have to be actually met by the pipe in the trench and to see how thick the walls of the pipe really need to be to withstand these forces. In doing this I think we shall find at least a partial answer to these questions, and I hope that it may lead to discussion that will put the available knowledge on the subject in more satisfactory shape.

In this discussion I shall consider only pipes 36 in. in diameter and over. In smaller pipes the strength requisite to make the pipe act as a sufficiently stiff beam to resist breaking in the trench may be an element of considerable importance in determining the thickness of the walls. In larger pipes this may also be a matter of some importance, but I do not think that it will often control.

Let us consider first the forces that act upon the pipe and the stresses resulting therefrom, which have to be met and resisted.

(1) *Internal Pressure.* This may be divided into two parts: (*a*) the ordinary working pressure, and (*b*) the pressure resulting from water ram. The ordinary working pressure is ordinarily known with comparative certainty. The amount to be allowed for water ram is seldom known with anything like accuracy. In some cases, as, for instance, siphons opening freely to aqueducts or chambers at their ends, the conditions are not such as to permit any appreciable amount of water ram to occur, and the question is practically eliminated. The amount of water ram that may be obtained in long pipe lines is practically limited by the fact that the gates used upon the line ordinarily require a considerable time for them to be closed, and the longer they take in closing, the smaller is the probable amount of water ram that will result from the closing. Obviously, the use of gates smaller in diameter than the pipe line will allow them to be closed more quickly and will, therefore, tend to larger pressures from water ram.

Similarly, the operation of gates by hydraulic or electric power may permit them to be closed more rapidly with a great increase in the amount of water ram. It will, therefore, be desirable when such valves are used to so gear the electric motors, or provide such small openings to the hydraulic cylinders, that the operation of the gates will be very slow, corresponding in speed to hand operation. As it is only the final closing that produces water ram, it would seem mechanically possible to devise a gate that could be quickly brought by power to three fourths closed, and then move very slowly to its seat, by some change in the operating mechanism.

Mr. Kuichling has told me that in the 24-in. Rochester pipe line, with hand-operated gates of the same size as the pipe, with the most rapid closing of the gates that could be practically carried out, he never observed a water ram amounting to more than one

half of the static pressure behind the gate. Probably with proper precautions, on a long pipe line, the water ram may be held within these limits, but there may be exceptions.

For instance, at Springfield, in a short line of 42-in. steel pipe leading from the settling basin to the filters, a balanced valve was provided for automatically controlling the water level on the filters. Only a part of the water went through this valve. On one or more occasions the valve has stuck until the water level got some distance beyond what was intended, and then closing quickly, the water ram behind the valve has been so great as to force water through various riveted joints in quarter-inch steel plates in a connected water wheel casing. I should say in this case that, with a total static head of only about 25 ft., the water ram must, at the very least, have been over 100 lb. per square inch, or ten times the amount of head.

The conditions in this respect correspond to those in the ordinary hydraulic ram, which, as is well known, will lift water to a height more than ten times as great as the distance that the water falls.

It is a good rule to design all the gates on main pipe lines so as to prevent water ram as far as possible, and then allow fifty per cent. in addition to the static pressure.

(2) *Stresses from Internal Strains in the Metal.* In cast-iron pipe there are internal strains in the casting resulting from unequal cooling. Such strains may be assumed to always exist, but in amounts varying very greatly with the excellence of the procedure in cooling the pipe after casting.

In steel pipe there are also internal strains in the steel plates, but these are usually of much less practical significance than those existing in cast-iron pipe because the material is malleable instead of brittle and is capable of being bent and considerably distorted without reduction in strength.

(3) *Stresses that come from the Weight of the Backfill.* If the backfill pressed equally on the pipe from all directions, or, in other words, if it acted as a liquid, these pressures would be radial and balance each other. But such backfill is never obtained. The inequality in the distribution of pressures varies with different materials, and with the manner in which those materials are packed.

The best published discussion of this subject that the speaker has found is by Prof. Arthur N. Talbot, Bulletin of the University of Illinois, No. 22, April 29, 1908.

Professor Talbot concluded, as a result of his investigations, that for ordinary conditions it was best to assume that the pipe carries on its upper half a weight equal to the whole weight of the material in the backfill above the pipe as a uniformly distributed load, and that this weight is transmitted through the sides of the pipe to the supporting material underneath. The result of the weight of this backfill is to tend to break the pipe. For a condition of uniform loading and uniform support along the pipe underneath, Professor Talbot finds as a result of his experiments, in which many pipes were actually broken, that $M = \frac{WD}{16}$, where M is the moment of bending forces tending to break the pipe at that point in the pipe where it is greatest; W is the total weight of backfill above a unit length of pipe, and D is the average diameter of the ring, which is practically the inside diameter plus the thickness.

For conditions of unequal loading and unequal support, the moment tending to break the pipe may be considerably greater than is computed by this formula.

(4) *Stresses due to the Beam Action of the Pipe.* We have considered thus far that the pipe was supported equally at every point along its bottom, and that the loading was equally distributed in the same way. As a matter of fact, this does not occur. The pipe is supported unequally along its length. With cast-iron pipe laid on blocking, and the blocking left in place, a considerable part of the pipe and its load after the trench is backfilled may still be carried on the blocks, and in this case the portion of pipe between the blocks acts as a beam, which must carry the weight of the pipe, the water in it, and the weight of the backfilling over it. If the trench is rock or has projecting bowlders, these may act in the same way and to an even greater extent, because the length of pipe between supports may be greater. Where a considerable length of pipe rests upon such projections on the bottom, there will obviously be a much greater tendency to break the pipe over these points because the forces acting upon a considerable length of pipe are concentrated on a small area.

(5) *Stresses Cumulative in Places.* The effect of internal water pressure is to produce circumferential tension through the whole section of the metal. The stresses due to unequal cooling of the castings are partly of compression and partly of tension, and may be both circumferential and longitudinal. The stresses due to the weight of the backfill are partly compression and partly tension, and are circumferential, when the pipe is uniformly loaded and supported. The stresses due to beam action are primarily longitudinal and, acting at 90 degrees from the others, do not need to be considered in connection with the circumferential strains. However, the effect of beam action is to increase the loading in places, and so increase considerably in those places the circumferential stresses due to the weight of the backfill.

For this purpose, limiting the discussion to pipes 36 in. in diameter and over, I shall consider at present only the circumferential stresses. These are cumulative in places. That is to say, there will be some points where the metal will be in tension from all of them, — from the internal pressure and from water ram, from the weight of the backfill, from the stresses due to unequal cooling of the metal, and also from the accumulated weight of the backfill caused by beam action.

When the accumulated stresses at any point exceed the ability of the metal to resist them, rupture begins and we have a broken pipe.

The formulas for the thickness of pipe in most general use take into account only the internal water pressure, including the ordinary working pressure and water ram. The other stresses are not taken into account.

These formulas have given reasonably satisfactory results for cast-iron pipe, because they have been based upon a working stress much below the stress that the metal is actually capable of sustaining, because the amount allowed for water ram has been in many cases above the truth, and because of an arbitrary addition to the computed thickness which adds considerably to the strength.

PROPOSED NEW METHOD OF COMPUTING THICKNESS OF CAST-IRON LIPE.

With Professor Talbot's work on the strength of pipes required to resist breaking in trenches, it seems possible to make a more rational calculation of the required thickness, based upon a higher unit working stress corresponding more nearly with the ultimate strength of the cast iron that is now available.

In carrying out this calculation no allowance is made at this time for internal stresses due to cooling, or for circumferential stresses resulting indirectly from beam action. It is assumed for the present that these and all other matters will be covered in the factor of safety, and that that factor will be increased if necessary to cover them in a subsequent revision of the calculation.

The calculation now made is to determine how thick the pipe must be to carry the stresses due to the backfilling as computed by Professor Talbot's formula, and at the same time to carry a stated internal pressure, with fifty per cent. addition thereto for water ram.

Let d = diameter in inches.

t = thickness in inches.

F = depth of backfill above top of pipe in feet.

s = permissible stress in pounds per square inch in cast-iron pipe, which I now take as 4 400 for an ultimate tensile strength of 22 000 lb., with a factor of safety of 5.

W = weight of fill over one linear inch of pipe at the rate of 115 lb. per cubic foot, the outside diameter of pipe being taken as 5 per cent. greater than d.

$$W = Fd\frac{1.05 \times 115}{144} = 0.84Fd.$$

M = breaking moment normally present from backfill, according to Talbot = $\frac{1}{16}WD$, D being the average diameter of the shell, which is about $1.025d$.

$$M = \frac{1}{16}1.025d(0.84Fd) = 0.0538Fd^2.$$

Resulting maximum circumferential stress in metal in lb. per sq. in. obtained by applying the usual formula, $M = \frac{1}{6}sbt^2$, b in this case being 1.

$$s_1=\frac{6M}{t^2}=\frac{0.323Fd^2}{t^2}.$$

The stress available for resisting the water pressure is 4 400 less this amount. Of this, one third is allowed for water ram and two thirds for static pressure.

The stress allowable for resisting the static pressure is thus

$$s_2=\frac{2}{3}\left(4\,400-0.322\,\frac{Fd^2}{t^2}\right).$$

H = head in feet that can be carried by a given stress:

$$s=\frac{r}{t}\text{ lb. pressure per sq. in.}=\frac{d}{2t}\times\frac{H}{2.31}\text{ and}$$

$$H=s\left(4.62\frac{t}{d}\right);$$

and for s_2 as reached above,

$$H=3.08\frac{t}{d}\left(4400-0.322\frac{Fd^2}{t^2}\right)=13\,500\frac{t}{d}-0.99F\frac{t}{d}.$$

If we had taken the weight of the earth backfill as 116 lb. per cubic foot, the 0.99 would have been unity, and we may make it unity for the purpose of simplifying the formula. We shall then have —

$$H=13\,500\frac{t}{d}-F\frac{d}{t}.$$

Our specifications allow a variation in the thickness of casting of 0.10 in. for large pipe. To insure that the stress shall not exceed the calculated amount at any point, if we could be sure that the specifications were literally complied with, it would only be necessary to add 0.10 in. to the computed thickness. This rule might be adopted for country work and where an occasional break in the pipe would not be of the greatest importance.

For city work, or where a break might do great damage, it would seem better to add 0.25 in. to the computed thickness, this being the allowance made in the Brackett formula in all cases for this purpose.

Solving the last equation for t, and making this addition. we have, —

For country work:

$$t=0.10+\frac{d}{27\,000}\left(H+\sqrt{54\,000F+H^2}\right).$$

For city work:

$$t = 0.25 + \frac{d}{27\,000}\left(H + \sqrt{54\,000F + H^2}\right).$$

This formula is not suggested as in any way final, but only for the purpose of discussion, and with the idea that it may possibly have in it some elements of a more rational calculation than are contained in the old formulas.

The formula for stress due to backfill is the one which Professor Talbot uses for ordinary backfilling of good material. With backfilling made of the very best material and with special care, the stress might be less. On the other hand, with poorly made backfill and with movements from settlement it might considerably exceed this figure. The most convenient way to allow for differences of this kind would be to allow more or less backfilling than the actual backfilling. For instance, with backfilling all made of coarse dry sand well tamped, it might be prudent to figure on a stress from backfill only three fourths as great as the actual backfill, while in rock trench with bowlders, or material that was sure to have subsequent settlements, the calculation might be made for a backfill fifty per cent. greater than the actual amount of backfill to be used, or even one hundred per cent. greater, if the conditions were very unfavorable.

For ordinary use it would seem fair to take 5 ft. of backfill in computing the thickness of pipe to be used in favorable trenches where the work was to be done with special care, and a larger amount up to 10 ft., or more, where the trench was deeper than usual and where there was rock or bowlders.

PIPE ACTUALLY BROKEN WITHOUT WATER PRESSURE.

In the first published paper of the American Society of Civil Engineers, Mr. Alfred W. Craven described some 72-in. pipe, $1\frac{3}{8}$ in. thick, laid in connection with the Croton Aqueduct, part of which was broken substantially without water pressure. The depth of backfill is not specifically stated in the paper, but from a statement of the load carried by the pipe I calculate that the approximate depth of backfill must have been about 10 ft. Taking the weight of the material from Mr. Craven's statement, the maxi-

mum stress resulting from this backfill was about 8 900 lb. per square inch. This, according to the statement, sufficed to break about 4 per cent. of the pipes.

In the *Engineering News*, December 15, 1904, Mr. Walter W. Patch describes 48-in. cast-iron pipe $1\frac{1}{4}$ in. thick under backfills ranging from 8 to 23 ft. He stated that in several places a number of adjoining pipes had developed longitudinal cracks in their entire length, etc. Using the formula as we have deduced it, the maximum stress in this pipe, with 23 ft. of backfill, would be 11 400 lb. per square inch.

Professor Talbot in his experiments tested pieces of 36-in. and 48-in. pipe from 1 in. to $1\frac{1}{2}$ in. thick carefully bedded in sand. Making the computation from the figures in his paper for the points where cracks first appeared, the stresses in 10 cases ranged from 15 000 to 41 000 lb. per square inch and averaged 25 000 lb.

In the two cases above mentioned, the inference may be drawn that, if the pipe was of full thickness and the iron of as good quality as may be reasonably assumed, the stresses that broke the pipe were about twice as great as those computed by the formula which is intended for uniform loading. In other words, the irregularities of the actual trench produced twice as much stress in certain places as was produced on an average by the careful loading in Professor Talbot's experiments.

A full reading of Professor Talbot's paper leaves little doubt of the actual doubling of these stresses at points in actual work, and at such points, with the calculation that I have just used, a factor of safety of only 2.5 will be left, certainly not too much to use for cast iron.

COMPARISON WITH BRACKETT FORMULA.

To see how the proposed new formula compares with the formulas in common use, I have taken the case of 42-in. pipe with 5 ft. of backfill. I have taken this because the question of the thickness and strength of 42-in. pipe has been under especial discussion in our office in the last year.

The results may be shown in tabular form.

Class of Pipe.	Standard Thickness in Inches.	Head in Feet Allowed by Brackett Formula.	Head Allowed by Formula now Reached.	
			Country Work.	City Work.
A	0.87	50	Negative.	Negative.
B	1.00	100	57	Negative.
C	1.13	150	127	45
D	1.27	200	198	122
E	1.40	250	257	188
F	1.53	300	314	247

This indicates that according to the formula, Class A pipe is not really safe for 42-in. pipe with 5 ft. of backfill, even where there is no internal water pressure, and "B" pipe is not safe for city work. This corresponds with the practice of our office, where "C" pipe has been the thinnest pipe ordinarily used, and with the observation that has been made that 42-in. pipe 1 in. thick, even when cast and laid under the most favorable conditions, is not very reliable for moderate water pressures. For higher pressures the results correspond more nearly to those by the Brackett formula.

With pipe larger than 42 in. the differences, especially for moderate water pressures, would be greater and the formula proposed calls in general for considerably thicker pipe.

The practical effect of this study is to show that with large pipes the stresses resulting from the backfill upon the pipe are material, and are added to those resulting from the water pressure, and that when they are taken into account the factor of safety is by no means as great as has been assumed. It is largely and perhaps principally for this reason that cast-iron pipe which has stood successfully hydrostatic pressure in the foundry breaks in the trench with a fraction of the test pressure, and it is for this reason that it is not safe to reduce the thickness of the walls of pipes as rapidly as increase is made in the ultimate tensile strength of the castings.

AS TO STEEL PIPE.

In the case of steel pipe the conditions are somewhat different. The pipe may be backfilled to the point where the stresses due to the backfilling are above the elastic limit, and when this happens the pipe becomes permanently deformed. That is to say, the pipe is flattened and the vertical diameter is less than the horizontal diameter. This is a fairly common occurrence.

Cast-iron pipe is not permanently deformed in this way because it is comparatively brittle and incapable of yielding to any considerable extent. When the stresses become too great it is broken.

The best explanation of this is that the steel plate is malleable, while the cast iron is not. The steel plate comes to the shop flat. It is bent cold to the shape of the pipe. This process stresses the metal beyond its elastic limit, and produces a set. Nevertheless, the plate is just as strong after the process as before.

In the same way, the pressure of the backfill in the trench may deform the pipe considerably, stressing it beyond its elastic limit, and producing other sets; but these do not have the effect of weakening the pipe.

Cast-iron pipe, on the other hand, is not malleable. To bend it out of its original shape by even the fraction of an inch breaks and destroys it.

I think this is the main reason why steel pipes are not broken in water-works service.

Other secondary reasons are, that steel pipe is relatively cheap and that such liberal allowances have been made that the walls have been relatively thick and the stresses low, and that when excessive water ram occurs in riveted steel pipe the riveted joints open up slightly by a momentary stretching of the rivets, or yield in other parts, within their elastic limit, and allow water to escape from the joints. If the excess pressure is not too great and too long continued the pipe comes back at once to its original size, and is as tight as before. The effect of this is to make the riveted steel pipe act as a relief valve for itself and protect it from what otherwise might be the injurious effects of water ram.

Lock bar pipe, a form of steel pipe which has recently come into use, has stronger and tighter longitudinal joints and does not act in this way, except by the elasticity of the metal.

ALLOWANCE FOR CORROSION.

Steel pipe has frequently been made thicker than otherwise necessary, with the idea that it would still be thick enough for strength after it had been reduced in thickness to some extent by corrosion. Experience shows that the troublesome corrosion is

mainly pitting. Ordinary pitting does not greatly reduce the strength of the pipe. It is very rare that the corrosion is so widely extended over the surface of the plate as to reduce the strength of the pipe.

Mr. John R. Freeman has shown that a moderate amount of corrosion does not reduce the strength of riveted pipe at all, as the plate at the outset is much stronger than the joints, and corrosion of the joints to a reasonable extent does not reduce their strength. Of course, ultimately there would be rusting off of rivet heads, etc., but practically speaking, the corrosion of riveted pipe that actually takes place during a long term of years does not appreciably reduce its strength.

In the case of lock bar pipe, the original strength of the pipe is greater and represents nearly the full strength of the steel plates. Corrosion of lock bar pipe would sooner have the effect of reducing its strength, and there would be more reason for making an allowance for corrosion than in the case of riveted pipe.

VARIATION IN THICKNESS OF PLATES.

The plates in steel pipes probably vary in thickness by nearly as large a percentage as the variation in thickness of the walls of cast-iron pipe. There is this difference, however. The thickness of cast-iron pipe is given as the average thickness, while the thickness of steel pipe is given as the minimum thickness, and the process of manufacture by rolls insures obtaining it at every point. The actual thickness of steel pipes will usually overrun the stated thickness by amounts which may be as high as four to eight per cent., and which are greatest with thin plates.

INCREASING THE THICKNESS OF STEEL PIPE TO PREVENT PERFORATIONS.

The practical difficulty that has been experienced with steel pipe up to the present time is that of perforations by pittings. In other words, the pittings after a while go entirely through the plate and make leaks. The perforations that occur in this way are easily plugged, but if they are numerous it is troublesome to take

care of them. Very few steel pipe lines have reached this stage up to the present time. In a few cases there has been electrolysis from trolley currents, which has greatly aggravated this condition. This condition is one that must be kept in mind in considering steel pipe, and it may be considered worth while to increase the thickness of the plates in some cases with the idea of putting off the time when there will be perforations. It could hardly be expected that increasing the thickness of the plates would prevent the perforations; it would simply postpone the time when they would occur.

It is my feeling that it will not generally pay to increase the thickness of steel plates very greatly because of this consideration, but that the money will be better spent in better coating and in more careful inspection of the steel plates, or, in other words, by preventing the pitting instead of trying to make the plate thick enough so that the pitting will not go through it.

So far as deterioration may be anticipated from electrolysis from escaping electric currents, it is my feeling that it is better to spend the money on special protective measures, such as insulation joints and surrounding the pipe with insulating material where it is near trolley tracks, rather than in increasing the thickness of metal with the idea of making it thick enough to stand such deterioration without perforation.

Mr. Lochridge tells me that the steel pipe line at Springfield passing under two trolleys and parallel with one of them for a distance, and connecting with the general distribution system in the city, shows no electrical current, indicating complete efficiency of the insulating devices that were used.

PRACTICAL CONSIDERATIONS IN DETERMINING THE THICKNESS OF STEEL PIPE.

In the first place, the pipe must have a thickness sufficient to make it reasonably stiff in handling and in resisting the pressure of backfill in the trench. This means practically the use of $\frac{3}{16}$-in. plates in 36-in. pipe, $\frac{1}{4}$-in. plates in 48-in. pipe, $\frac{5}{16}$-in. plates in 60-in. pipe, and $\frac{3}{8}$-in. plates in 72-in. pipe. These may be taken as the minimum thicknesses below which it will very seldom pay to

go. In deep trench the plates must be thicker, or else the pipe must be surrounded with concrete, or otherwise stiffened. These minimum thicknesses may be used wherever they are strong enough to resist the internal pressure, and where they are not, additional thickness may be calculated so that the stresses in the metal from water pressure will not exceed the limits that are to be allowed.

The strength of the steel plates in pipes ranges from fifty to sixty-five thousand pounds per square inch. The elastic limit is not less than thirty thousand pounds per square inch. The safe working stress on the steel may be taken at fifteen thousand pounds per square inch. If the allowance for water ram is taken as equal to fifty per cent. of the static pressure the permissible stress for static pressure will be 10 000 lb. per square inch.

If lock bar pipe is used, and the strength of the joint as a minimum is taken as ninety per cent. of the strength of the plate, we may use a working stress of 9 000 lb. per square inch.

If double riveted pipe is used, with a strength of joint assumed to be seventy per cent. of the strength of the plate, we may use a working stress of 7 000 lb. per square inch.

Even with lock bar pipe it may be prudent to reduce the working stress below 9 000 lb., and this is more readily done because the added thickness of metal costs so little.

In the Springfield 42-in. lock bar pipe line, the maximum stresses under working conditions obtaining in the pipe line are as follows.

Above Provin Mt., Ordinarily Protected from Water Ram.			Below Provin Mt., Subject to Ordinary Water Ram.	
Thickness of Plate, In.	Maximum Static Head, Ft.	Corresponding Stress in Steel in Lb. per Sq. In.	Maximum Static Head, Ft.	Stress in Steel, Lb. per Sq. In.
$\frac{1}{4}$	243	8 840	...	.....
$\frac{5}{16}$	298	8 700	236	6 860
$\frac{3}{8}$	351	8 530	284	6 900
$\frac{7}{16}$	...	.....	347	7 250

It may be thought that these stresses are unnecessarily low and that thinner plates might have been used with perfect safety. But the pipe is relatively cheap and the advantage of having it so strong that there is not even a remote probability of its being broken by water ram that may sometimes occur in excess of the one that is calculated is worth getting.

Important lines of steel pipe have been designed with working stresses on steel of 12 000 to 13 000 lb. per square inch, but this has been with triple riveted double butt-strap riveting, and for lines absolutely protected from water ram.

In conclusion, it is my impression that up to the present time practice with steel pipe and cast-iron pipe has been rather unequal. Steel pipe has been made stronger than cast-iron pipe, but this has been justified by the cheapness of the material, by the lack of certainty regarding some of the conditions, and by the advantage of having the pipe strong beyond any possible question.

DISCUSSION.

MR. LEONARD METCALF.* Mr. President, it seems to me that Mr. Hazen has done us a genuine service in bringing this matter to our attention, for it is one of great importance. Of course most works have pipes which are of comparatively small diameter, where these influences of which he has spoken are not so serious. At the same time there are enough pipe lines, particularly in our larger cities, to make the matter of importance, bearing in mind the heavy damages which result from failure of pipe lines. I would like to ask Mr. Hazen at about what point he finds that the influences of the depth of backfill affect the pipe. He spoke of 36-in. and larger; isn't the limit, perhaps, somewhat below that?

I have laid Class A, 20- and 24-in. pipe to a depth of about 20 ft., if I remember rightly, which are doing good service to-day, — the depth varying from 5 ft. to twenty-odd feet in a line about eight miles in length, running through the fields and woods.

There was a case of failure in a 42-in. pipe line of the Pennsylvania Water Company. Mr. Kuichling brought this same matter to my attention a year or two ago and spoke of that pipe line as furnishing a very good example of the effect of the backfill. The backfill was only, I think, something like four or five feet, and yet that pipe line broke and had to be replaced. There was some considerable expense in making good the damage done by the

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break, and a long line of the pipe was taken out and replaced with pipe of heavier weight.

THE PRESIDENT. I don't know whether it would help any if I related a little experience which I had with drain pipe. I found that by very careful tamping on the horizontal diameter and below we could add a great deal to the strength of the drain pipe, that is, to its power to resist the pressure of the backfill. I had the pipe put in and it failed; and I had it put in again and great attention paid to the ramming of the earth below and at the sides of the pipe, and it then stood the pressure of the fill. It seems to me that ramming the earth well opposite the horizontal diameter of the pipe will help it to resist the thrust and cause it to stand a great deal more pressure.

MR. ROBERT S. WESTON.* I would like to ask Mr. Hazen if he does not think that the relative greater liability of the steel plate to corrosion has influenced the choice of the thickness of the plates to some degree in another form, — even to increase the thickness beyond what is absolutely necessary.

MR. ALLEN HAZEN. Replying to Mr. Metcalf, it is obvious that the stresses that it was the object of my paper to call attention to will also exist in pipe less than 36 in. in diameter, but they will clearly be more important in large pipe than in small pipe. I have not attempted to set a limit to the size of pipe for which they should be taken into account, but as the matter is much more important for large pipe I thought it best to limit the discussion for the present to such pipe. I have endeavored to present a subject that seems to me to be of the very greatest importance, and that has been, as far as I know, largely overlooked in the design of cast-iron pipe, with the object of getting it discussed and of finding how far it should properly enter into future designs. When we are through with the discussion it may be that an answer to Mr. Metcalf's question will be found.

As Mr. King suggests, ramming the backfill on the sides increases the stability of the pipe. Professor Talbot's paper discusses this very well, and it may be read with profit by all interested in this subject. Having the material packed firmly against the sides and quarters of the pipe is more important than having

*Sanitary Expert, Boston, Mass.

a support underneath. In fact, the ideal position of a pipe would be to have it supported so firmly on the quarters that it would not bear underneath at all.

Mr. Weston's questions are largely answered in the paper itself. Steel pipe has frequently been made thicker because of anticipated corrosion, but I am disposed to think that generally it will be better for us to put the money that otherwise might be spent in thicker plates, in better coating and better inspection of the plates for surface defects, and into better devices for protecting the pipes against stray electric currents.

MR. EMIL KUICHLING* (*by letter*). This paper is a very valuable addition to the literature of the subject, as it brings out clearly some of the defects in the usual formulas for computing the thickness of water pipes, and indicates how a more rational formula should be made. In dealing with the internal pressure due to water ram, the author states that such pressure is practically limited by the fact that the closing of a stop valve or gate in a large pipe ordinarily requires considerable time. Such gates are usually geared in the ratio of 3 or 4 to 1, and there are generally three screw threads per inch on the stem, thereby requiring from nine to twelve revolutions of the operating pinion to lower the gate disk one inch. When the bottom of the disk reaches the axis of the pipe, an appreciable hydraulic pressure against the disk begins to develop which causes friction on the guides and corresponding resistance to the turning of the stem. This resistance increases rapidly during the last quarter of the descent, so that the final inch may require the utmost exertion of three or four men for at least one minute. Against a static pressure of 50 lb. per sq. in., about twenty minutes are needed to fully close a 24-in. valve and thirty minutes for a 36-in. valve.

The writer has made a number of observations of the increase of pressure caused by closing a 24-in. stop valve in a long line of 24-in. cast-iron pipe. The point of observation was 2.53 miles from the supplying reservoir, the valve was 2 100 ft. beyond, and while the valve was shut the static pressure at said point was 49 lb. Before closing the valve the hydraulic pressure was 40.2 lb., and the water was flowing through the pipe with a mean velocity

* Consulting Engineer, New York.

of 3.45 ft. per second. The valve was closed as rapidly as possible in about twenty minutes, and during the last four minutes the pressure rose to a maximum of 65 lb., after which it oscillated rapidly from 40 to 64 lb. for a few seconds and then gradually reduced in two minutes to a range from 42 to 57 lb. In the course of eight minutes more, the range was from 46 to 52 lb., with increasing intervals of time between the pulsations, and at the end of fifteen minutes the pressure varied little from 49 lb. These observations were repeated several times subsequently with the same general results, and hence it was concluded that for long and large pipe conduits, the water ram caused by closing a stop gate would not induce an internal pressure greater than 1.5 times the static pressure.

In the small distributing pipes of a municipal water works, water rams of much greater magnitude may be expected by the rapid closing of fire hydrants and hydraulic motors of large size; but as this subject is not under consideration, further reference thereto will be omitted. It may also be remarked that stop valves larger than 24 in. in diameter are usually provided with by-pass valves which are closed after the main valve has been shut and the velocity of the water in the pipe has been greatly reduced; and if by carelessness the by-pass gate happens to be closed, the men who attempt to close the main valve will usually become aware of the fact during the latter part of the operation by the increased frictional resistance of the large valve stem.

The stresses caused by the weight of the backfill are highly important and vary much with the condition of the material in regard to moisture. Even when the material is well compacted by ramming, a settlement usually occurs after water has percolated freely into it, and with such settlement a greater load upon the pipe must ensue. Little is yet known of the magnitude of this external pressure, or of the manner in which it is distributed over the upper surface of a large pipe. So far as the writer is aware, the only experimental data that are available in this direction are those that pertain to the deformation or flattening of a few cast-iron and riveted steel pipes, the former being given in Prof. A. N. Talbot's Bulletin No. 22 of the University of Illinois, 1908, and the latter in the paper of D. D. Clarke, chief engineer

of the Portland, Ore., water works, in Transactions of the American Society of Civil Engineers, Volume XXXVIII (1897), pages 93–114, together with some observations made by the writer at various times between 1874 and 1896.

In view of the fact that settlements of the backfill usually appear to extend nearly uniformly across the entire width of the trench, the writer has assumed that the pressure thus induced upon the upper surface of the pipe is distributed uniformly in a vertical direction over its width and that no considerable pressure is exerted horizontally against the sides of the pipe; also, that the pipe bears uniformly upon its earthen foundation in the same manner as the backfill on the top. These assumptions, moreover, facilitate the computation of the bending moments, stresses, and deformation in a ring-shaped section. On this basis the formula for the magnitude of the elastic flattening or reduction (y) of the vertical diameter of a relatively thin pipe becomes: $y = \frac{WD^3}{96EI}$, where W is the uniformly distributed external load acting vertically on the pipe per unit of length; D is the mean diameter of the section, or the internal diameter plus the thickness, t; E is the modus of elasticity of the metal of which the pipe is made, and I is the moment of inertia of the longitudinal section of the wall of the pipe per unit of length, which is expressed by $\frac{t^3}{12}$. For the cast iron of the 36-in. and 48-in. pipes used in his experiments, Professor Talbot deduced the approximate average value $E = 11\,000\,000$ lb. per sq. in.; and for wrought-iron and steel plates the writer has assumed the usual mean value $E = 30\,000\,000$ lb. per sq. in. The weight W may also be expressed by $W = wD$, where w is the equivalent vertical load in pounds per unit of area. Taking the inch as unit and replacing I by its value $\left(\frac{t^3}{12}\right)$, we now have —

$$y = \frac{wD^4}{8Et^3}, \text{ whence } w = \frac{8Et^3y}{D^4},$$

which is the expression for the uniformly distributed vertical load or weight of backfill in pounds per square inch of horizontal surface required to produce a given deformation or reduction (y) of the vertical diameter of the pipe.

The values of w thus computed from the observed values of E, t, y, and D may now be compared with the observed or estimated weight w_1 per square inch of the backfill, and the writer has arranged some of the available data in the following table, in which the first four items refer to cast iron, and the remainder to soft steel pipes.

Internal Diameter. In.	Thickness (t). In.	Mean Diameter (D). In.	Deformation (y). In.	Estimated Load (w_1). Lb. Sq. In.	Computed Load (w). Lb. Sq. In.	Ratio $\frac{w}{w_1}$	Backfill.
48	1.25	49.25	1.00	37.2	29.2	0.785	S*
48	1.50	49.50	1.00	57.2	49.4	0.864	S*
36	1.00	37.00	0.80	49.6	37.5	0.754	S*
36	1.25	37.25	0.50	63.8	44.6	0.700	S*
42	0.238	42.238	0.438	2.92	0.445	0.153	S*
42	0.203	42.203	3.50	4.69	2.216	0.472	SC†
42	0.203	42.203	2.75	4.69	1.741	0.372	SC†
42	0.203	42.203	1.00	3.61	0.633	0.175	WS‡
42	0.203	42.203	0.563	2.92	0.356	0.122	S*
35	0.203	35.203	3.00	3.13	3.922	1.255	SC†
33	0.203	33.203	0.375	3.19	0.620	0.194	S*
33	0.203	33.203	0.188	1.67	0.310	0.186	S*
38	0.25	38.25	2.00	5.83	3.504	0.600	WC§
38	0.25	38.25	1.50	5.83	2.628	0.450	WC§

* Weight of dry sand given at 80 lb. per cu. ft. S = Dry Sand.
† Weight of sandy clay estimated at 90 lb. per cu. ft. SC = Sandy Clay.
‡ Weight of wet sand estimated at 100 lb. per cu. ft. WS = Wet Sand.
§ Weight of wet clay, etc., estimated at 120 lb. per cu. ft. WC = Wet Clay and Stones.

The values of the ratio $\left(\frac{w}{w_1}\right)$ in the foregoing table exhibit a wide variation, as is to be expected. In the case of the 35-in. steel pipe, it is probable that the filling under the lower quarters of the pipe was not well done, and that the pipe rested mainly on a narrow strip of the bottom, whereby the deformation was greatly increased.

Where a good support on the bottom is given by dry or well-tamped sand, it seems that the external load due to the backfill may be taken at from one fifth to one half the weight of the material, distributed uniformly on the horizontal projection of the pipe, when the depth of covering is from 3 to 7 ft.; but when the backfill is heavily loaded, a corresponding addition must be made, as indicated in the case of the cast-iron pipes. The data are not sufficiently numerous and diversified to give a clear view of the matter, as so much depends on the nature of the backfill and the

way it is placed under and over the pipe; hence until further investigations have been made, it will be prudent to assume that in locations where the right of way for a pipe conduit is not affected by heavy moving loads, such as locomotives, road rollers, etc., at least two thirds of the weight of the backfill acts upon the pipe as a uniformly distributed vertical load and produces circumferential bending stresses in the metal.

The magnitude of the maximum stress s in the outermost fiber, due to the said uniform vertical external load (w), is found by placing the moment or modulus of resistance equal to the maximum bending moment: $M=\frac{wD^2}{16}=\frac{st^2}{6}$, whence $s=0.375w\left(\frac{D}{t}\right)^2$. Now, if we assume that the backfill weighs 115 lb. per cu. ft. and is 6 ft. deep, the weight will be $w_1=4.8$ lb. per sq. in.; and if two thirds thereof acts vertically upon the pipe as aforesaid, the value of w will be $w=\frac{2}{3}w_1=3.2$ lb. per sq. in., whence $s=1.2\left(\frac{D}{t}\right)^2$. In general, the ratio $\left(\frac{D}{t}\right)=37$ for the thinnest large cast-iron pipes and 193 for the thinnest large steel pipes; hence we have in general the maximum stress due to bending, $s=1\,643$ lb. per sq. in. for cast iron, and $s=44\,699$ lb. per sq. in. for steel. This latter value of s is greater than the elastic limit of the metal, and hence the pipe will become permanently flattened unless a considerable horizontal pressure is exerted on the sides of the pipe. From the foregoing experimental data it does not seem expedient to regard the ratio $\left(\frac{w}{w_1}\right)$ as being less than 0.25 under the most favorable conditions, and if the weight of the backfill is only 96 lb. per cu. ft. with a depth of 3 ft., we will have $w=\frac{w_1}{4}=2.0$ lb. per sq. in., and $s=0.75\left(\frac{D}{t}\right)^2=27\,937$ lb. per sq. in. for the thinnest steel pipes. These figures will suffice to show that the stresses caused by the backfill are of much importance when the pipe is empty or internal water pressure is small.

The question now arises whether the tensile bending stress due to the backfill is to be added to the tensile stress resulting from the internal water pressure, or whether the latter does not

eliminate the former in large degree by reducing the initial deformation or flattening. There can be little doubt that a large internal water pressure will tend to restore the original circular cross-section of the pipe, but in doing this work the sides of the pipe will recede slightly from the adjacent earth and thus reduce or eliminate any existing lateral horizontal pressure. This action must be followed by a corresponding increase of the vertical external pressure until equilibrium is finally established with a somewhat greater external load than while the pipe was empty, and hence also with a slight deformation and a resulting tensile stress that will add to the stress produced by the internal water pressure. It is difficult to determine the magnitude of this final flattening and its accompanying tensile stress. In the case of cast-iron pipes it will usually be small, but in the case of thin steel pipes it may attain a considerable magnitude. Under existing conditions of inadequate experimental data, it will, therefore, be prudent to consider that the backfill will produce an appreciable deformation and tensile stress in large water pipes, as done in Mr. Hazen's formula.

Another feature in the case is the external pressure of the atmosphere against the wall of a pipe from which the water has been withdrawn, as when a valve is closed and a blow-off is opened. The backfill is usually more porous above the pipe than below the same, so that momentarily a greater atmospheric pressure will develop on the upper surface than on the lower one when all internal pressure ceases; and if the material is moist and plastic, the air pressure on the surface of the backfill will act like an applied load at the rate of 14.7 lb. per sq. in., of which the greater part will be transmitted to the pipe. This atmospheric pressure is equal to the weight of a column of earth 22 ft. high at the rate of 96 lb. per cu. ft. No provision for admitting air into cast-iron pipes by means of automatic vacuum valves is usually made, but if we assume a depth of 10 ft. of backfill at 115 lb. per cu. ft. in conjunction with the atmospheric pressure, the total external load will become $w_1 = 23$ lb. per sq. in.; and if three fourths of this load acts vertically upon the upper surface of the pipe, as indicated by Professor Talbot's data in the foregoing table, we will have $w = 17.25$ lb. per sq. in., and the cor-

responding stress $s = 0.375w\left(\frac{D}{t}\right)^2 = 8\,857$ lb. per sq. in. in the thinnest cast-iron pipe for which the ratio $\left(\frac{D}{t}\right) = 37$. This is an extreme case, as there will be a little air pressure on bottom of pipe, owing to the density of the material and the high resistance to the circulation of air therein.

Severe circumferential stresses are also caused in cast-iron pipes by the settling of several lengths. This produces an intense leverage pressure in the lead joint on the top and bottom of the spigot, with the probability that the fillet or bead comes in contact at the top with the bell, thus making a concentrated load of great magnitude. If we assume that this vertical load is not concentrated, but is distributed uniformly over the horizontal diameter D and on an effective width of 2 in., and is resisted by a length of $b = 12$ in. of the spigot end of the pipe, we will have the relation $M = \frac{2wD^2}{16} = \frac{sbt^2}{6} = 2st^2$, whence $w = 16.s\left(\frac{t}{D}\right)^2$. Taking the stress s at its limiting value for cast iron in flexure, viz., $s = 27\,000$ lb. per sq. in., as per Professor Talbot's tests, we will have for a 36-in. cast-iron pipe 1 in. thick a limiting leverage load on the lead joint $w = 316$ lb. per sq. in. on width of 2 in. Such a load is very easily developed by the settling of a few heavy pipes in a yielding soil.

In addition to the computable stresses mentioned in the foregoing, there are a variety of other stresses that should be taken into consideration, as cited in Mr. Hazen's paper. Concerning the magnitude of these other stresses, little information of a definite character is available, and hence allowance for them must be made in the adopted factor of safety. Mr. Hazen has shown very good reasons for modifying our previous formulas for the thickness of large cast-iron pipes, and submits a rational substitute. The only point that the writer can raise is in regard to the ultimate tensile strength of that quality of cast iron which is now commonly used for making pipes. The author has adopted for this a value of 22 000 lb. per sq. in. Not many years ago water-works engineers were satisfied if the direct tension tests of samples of the metal showed an ultimate strength of about 16-

000 lb. per sq. in. For breaking stress in bending, values of from 30 000 to 40 000 lb. per sq. in. are often obtained, but as these figures are commonly based on the erroneous assumption that at rupture the neutral axis lies at the middle of the rectangular cross-section of the test bar, it is clear that they cannot represent the normal tensile strength of the metal which is brought into action by the internal water pressure. The use of $s = 22\,000$ thus implies a marked improvement in pipe foundry practice which deserves some explanation, and the author will add much to the value of his paper by submitting a brief abstract of recent tests of pipe metal on which his figure is based.

ARTHUR N. TALBOT, ESQ.* (*by letter*). Mr. Hazen has referred to the experiments on the strength of cast-iron pipe to resist external load made at the University of Illinois. It is evident from a study of the question that the actual bending moment brought upon pipe depends upon the method of applying the load (its distribution over the pipe) and upon the way the pipe is bedded. If the pipe is supported along the bottom element alone, and the load is applied along the top element, the bending moment at a longitudinal section at the top or bottom of the pipe will be $0.16QD$ where Q is the concentrated load applied at the crown and D is the diameter of the ring. If, now, the load is distributed uniformly in a horizontal direction over the pipe, and if the upward pressure on the bed is similarly uniformly distributed, the maximum bending moment is $\frac{1}{16}WD$ where W is the total vertical load on the pipe. Lateral pressure against the pipe will reduce this maximum bending moment. If this lateral pressure is uniformly distributed and if q represents the ratio of the horizontal to the vertical intensity of pressure, the maximum moment will be $\frac{1}{16}(1 - q)WD$, where W is the total vertical load on the pipe. It is seen that if the intensity of the horizontal pressure is the same as that of the vertical pressure, $q = 1$ and the bending moment becomes zero at all points. Any horizontal or lateral pressure if uniformly distributed will decrease the bending moment developed. However, study of tests made on pipe embedded in sand, and consideration of the conditions which will

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exist in the bed and in the back-filling of a pipe line, indicate that the effect of this lateral pressure may be expected to be offset by variations from uniform distribution of pressure on the bed or of the load on the pipe and, therefore, that $\frac{1}{16}$ is as low a coefficient as should ordinarily be assumed in calculating stresses. Under these assumptions the formula given by Mr. Hazen for the bending moment stress developed is correct, and probably it is as generally representative as can be made with our present knowledge. It may need modification for unusual conditions of bedding and backfilling, and of course in deep trenches the full weight of the earth may not come on the pipe.

The analysis given in Bulletin No. 22 of the Engineering Experiment Station of the University of Illinois, referred to by Mr. Hazen, brings out the importance of giving especial care to bedding and backfilling. It is very important that the pipe shall not rest along an element at the bottom, or that after a little settlement the main pressure shall not be upon this line. If the layer of earth immediately under the pipe is hard or uneven, or if the bedding at either side of the pipe is of soft material or is not well tamped, the result is greatly to increase the bending moment developed by the external load and hence to increase the tendency of pipe to fail. This condition may be aggravated in the case of a pipe with stiff bell or hub when settlement brings an excessive proportion of the bearing at the bell, resulting in a distribution of pressure far from uniform. In bedding the pipe in hard ground it is better to form the trench so that the pipe will be fairly free along the bottom element, even after settlement occurs, and in such way that the bearing pressure may be greatest near the one-third points of the horizontal diameter, or even farther out. Care in this matter will reduce the bending moment stresses in the pipe.

In case the pipe is bedded in loose material, the effect of settlement will be to compress the earth immediately under the bottom element of the pipe more than at either side, with the result that the pressure will tend toward concentration at the center. Careful filling and tamping at the sides will result in giving lateral support to the pipe. In a similar manner the filling and tamping over the top may be made in such a way as to

reduce the bending moment stresses — the fill should be more thoroughly compacted at the sides and over the quarter than over the top of the pipe.

Attention should be called to the fact that the analysis of effect of external load assumes that the distribution of the pressure is by means of the earth under and over the ring and that this earth will be compressed in somewhat the same way as other materials of construction under compression. Unless the earth has elasticity, the assumed distribution of pressure cannot occur. Further, to secure the uniform distribution assumed, the pipe itself must deform enough to allow for the movement of the earth which takes place under this compression. This is especially true with reference to the presence and utilization of lateral restraint, and a ring which does not deform laterally will not develop lateral pressure in the adjoining earth under ordinary conditions of moisture and filling to any great extent. As the conditions of earth and moisture produce mobility and approach hydrostatic conditions, the necessity for this elasticity and movement does not exist, but here the lateral pressure approaches the vertical pressure in amount and the bending moment becomes relatively smaller.

Enough has been said to indicate the importance of care in bedding pipe and in filling over them and to indicate the great difference in the amount of bending moment stresses developed with different conditions of bedding and filling. Where there is any question of needed strength, it will be money well spent to use especial care and precaution in bedding the pipe and in filling around and over it.

Mr. Hazen refers to the smaller liability of steel pipe to breakage. One factor which gives additional security to the steel pipe, and which has not been recognized, is the advantageous distribution of external pressure above and below and laterally, due to the larger deformation under external load. Under the distortion of section the pressure will be greater at points away from the top and bottom element and the lateral pressure against the pipe will also be greater. The change in the horizontal and vertical diameters of a steel pipe 0.2 in. thick will be seventy-five times as great as that of a cast-iron pipe 1 in. thick under the same

load and with the same distribution of pressure. The higher deformation will permit the development of lateral pressures which will much reduce the bending moment stresses brought upon the pipe by the external loads. Although the tests heretofore referred to show that 48-in. cast-iron pipe will give a change in diameter of from ½ in. to 1½ in. before breaking, the amount of change in diameter where internal pressure constitutes the principal force producing stress will be slight, and the yielding of the earth will not be sufficient to permit the development of much lateral pressure. In thin steel pipe the change in diameter under ordinary loads is greater. This point, of course, is only one item in any comparison of steel and cast-iron pipe.

It does not seem logical to make the allowance for water hammer in a pipe line dependent upon the amount of the static pressure, as the conditions of pipe line flow vary so greatly, and especially as the amount of water hammer developed depends upon velocity of flow rather than upon the static pressure existing.

Mr. Hazen is to be commended for calling attention to the importance of the stresses due to external load in large pipes subjected to low internal pressure. The paper is an interesting presentation of the matter.

MR. W. C. HAWLEY * (*by letter*). This paper calls attention to a fact which, while it has been understood by a few engineers, has not been generally recognized by the average water-works man. Up to a certain diameter, the external pressure, so far as the weight of the backfill is concerned, need not be considered, but just what this limiting diameter is has not been stated. It is the writer's belief, however, that the author, in considering pipes 36 in. in diameter and larger, has indicated the point at which the weight of the backfill must be considered, except, possibly, in those cases where the pipe is laid at excessive depths. This is borne out by the experience with the Pennsylvania Water Company's line to which Mr. Metcalf has referred. This line was laid for the purpose of conveying water from one distributing reservoir to another, and two miles of it were of 42-in. pipe, the other two miles being of 30-in. pipe. The 42-in. pipe was laid with an average depth of cover to top of pipe of about 4.5 ft.,

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but there were a number of places where for short distances it was from 9 ft. to 12 ft., and in two cases it was at least 18 ft. The water pressure on this line reached as high as 150 lb. per sq. in. There were but two weights of 42-in. pipe used: Class A, which weighed 400 lb. per ft., with a thickness of approximately 0.86 in., and Class B, which weighed 450 lb. per ft., with a thickness of approximately 0.97 in. The deep trench, with one exception, occurred on the B class of pipe. The exception was that with 18-ft. cover near the first reservoir, and it is interesting to note that two of the light-weight pipe failed in this deep trench.

The serious trouble on this line, however, occurred with the Class B pipe at a point where the pressure was in the neighborhood of 125 lb. and where the backfill did not exceed from 3 to 5 ft. The failures were so serious that a mile and one half of the 42-in. pipe were taken up and replaced with 36-in. pipe.

The two miles of 30-in. were of a uniform weight of 250 lb. per ft., with a thickness of about 0.82 in. This pipe was laid with an average depth of cover of about 4 or 5 ft., but with maximum depths of 8 to 12 ft. The highest pressure carried was about 130 lb. to the sq. in., and the backfill at this point was only 2 or 3 ft. The weight of this pipe was calculated by the same formula that was used for the 42-in. pipe; it was purchased from the same foundry under the same specifications at the same time and neither was inspected at the foundry. Both pipes were laid in 1900 by the same contractor, and the 30-in. is still in service without a single failure due to any fault of the pipe. This would seem to indicate that the smallest diameter of pipe which requires the consideration of the external pressure lies between 30-in. and 42-in. It is interesting to note, however, that nearly all of the 30-in. pipe was laid in an earth trench with good material on which to place the pipe, while most of the trench for the 42-in. pipe was in stony ground or rock.

As above stated, there is about one-half mile of the 42-in. pipe still in service. Specifications under which this pipe was laid called for it to be laid on blocks. This was not done in all cases, but within the last fifteen months two pipes have burst on account of the concentration of the load at one point. In each case the pipe was resting on a projection of rock in the bottom of the

trench. In contrast to this, in the mile and one half of 36-in. pipe which was laid by the same contractor in the same trench after the removal of the 42-in pipe, but under rigid inspection by a man experienced in pipe laying and which was not laid on blocks, there has not been a single failure, not even a serious leak, in the eight years that it has been in service. The 36-in. pipe was, however, materially heavier than the 42-in. pipe.

The stresses from internal strains in the metal and the stress due to improperly bedding the pipe cannot and need not be taken care of in a formula for thickness of pipe. The former can be largely eliminated by proper inspection at the foundry by an experienced inspector. The latter requires good honest work in laying the pipe. The inspection necessary to secure the desired results will cost far less than the additional metal which will be required if allowance is made in the formula to cover them, to say nothing of the cost of damages and the annoyances caused by the interruption of supply after the pipe has been laid and put into service.

The thorough bedding of the pipe is a more important matter than is generally recognized. The writer had occasion some years ago to reconstruct a water-works plant and to materially increase the pressure on a portion of its distribution system. The pipe in this system, or at least a considerable part of it, had been laid to stand a pressure of not to exceed 90 lb. per sq. in. As a matter of fact, for years the pressure has seldom if ever exceeded 40 to 65 lb. Some of the 4, 6, and 8 in. pipe weighed respectively 20, 30, and 40 lb. per ft. With the completion of a new reservoir, the pressure was increased to from 125 to 165 lb. per sq. in. The pipes, though of light weight for such pressures, had been in the ground long enough to have become thoroughly bedded, and there were but two pipes burst as the result of increasing the pressure, both of which were light-weight 12-in. pipes. The writer is of the opinion that had this pipe system been subjected to such a high pressure when it was first laid, there would have been a large number of breaks.

There is a cause for the failure of cast-iron pipe which was very forcibly called to the writer's attention some years ago by a carload of pipe which had been in a railroad collision. The pipe had

been partially thrown from the car, some of it badly broken, other lengths merely cracked. It was reloaded and upon its arrival at its destination, the broken and cracked pipe was rejected. A very careful inspection was made of each length, and special attention was given to sounding each length as it hung supported from the derrick by striking it with a hammer. At least three men inspected the pipe on the ground before it was put in the ditch, with the result of still more rejections. As soon as the pipe was laid, it was tested under pressure and several lengths failed. An inspection of the breaks showed that the pipe had been cracked on the inside where it could not be seen by the inspector, but that the crack had not extended through the shell of the pipe. Doubtless the cause of the crack was a sharp blow received on the outside at the time of the collision, which had opened the crack on the inside of the pipe, but was not sufficient to cause a crack through the entire thickness of the metal. The writer's experience since that leads him to believe that a considerable number of the failures of cast-iron pipe are due to blows received in loading, transportation, or unloading, — especially unloading, — and that special care must be exercised to prevent pipe being damaged in this way.

The writer notes that in developing the formula for the thickness of cast-iron pipe, the author has used 22 000 lb. as the tensile strength of the metal. Doubtless he has information which leads to the use of this seemingly high figure. So far as the writer is concerned, he has for some years past used 18 000 lb., and from rather recent figures is inclined to believe that 20 000 lb. could be safely used.

Mr. Allen Hazen (*by letter*). The author will agree at once that the subject of "water ram" was treated in an inadequate way, as was perhaps natural, because it was not the main subject under discussion. The author hopes that a separate paper upon this subject may be presented by some one who is well qualified to do it.

The tensile strength of cast iron, taken in the calculation as 22 000 lb. per sq. in., is probably a little above that which can ordinarily be obtained at the present time. Mr. Hawley's suggestion of 20 000 lb. as representing the best current work is probably about right. The calculation was first made in con-

nection with a discussion in which it was proposed to use a superior quality of cast iron with a higher tensile strength, and the figures so made were not reduced, as perhaps it would be well to do now, in applying them to present conditions.

On the other hand, the average strength of the cast iron used in the culvert pipes broken in Professor Talbot's experiments, computed by solving the formula backward, gave an average value somewhat above the 22 000 lb.

The fact that lateral pressure is developed largely in connection with the deformation of the pipe, growing out of its elasticity, is an interesting one, and the points made by Professor Talbot and Mr. Kuichling, based upon this general idea, are most interesting and important.

Mr. Kuichling's data as to the weight actually borne in certain cases, computed from the measured distortion of the pipe, is most interesting. This seems to indicate in general a smaller proportion of the weight of the fill actually carried by the pipe than is assumed by the formula. However, the maximum results will control rather than average results, and bearing this in mind the substantial agreement between the formula and the observations is gratifying. Professor Talbot's endorsement of the general method is most important.

It is gratifying that Mr. Hawley has put on record particulars as to one of the lines of thin pipe that has broken badly. The author believes that there are a number of other cases of interest and importance known to members of the Association, and he hopes that further particulars of these may be put on record at some time.

THE MECHANICAL FILTRATION PLANT AT NEWPORT, R. I.

BY ROBERT E. MILLIGAN, MANAGER NEW YORK CONTINENTAL JEWELL FILTRATION COMPANY.

[*Read December 14, 1910.*]

The reinforced concrete filtration plant of the Newport Water Works, Newport, R. I., was contracted for in the early part of 1909 and completed and placed in operation in May, 1910.

Considerable elasticity in operation is possible because of the design of this plant, as sedimentation with or without coagulation, separate coagulation within the basin provided, sterilization by hypochlorite solution before or after filtration, and aëration are all arranged for in conjunction with mechanical filtration proper.

The plant consists essentially of two sedimentation or settling basins arranged to operate as one basin under normal conditions, a distinct coagulating basin through which the settled water must pass to the filters, the filters themselves and the clear water well below them.

Fig. 1, Plate I, shows the general design and relation of these settling basins and the coagulating basin to the filters proper which are contained within the house shown in the middle distance, the background indicating the pumping station of the water works, to which the new structure is joined by a covered passage and machinery room. The settling basins are arranged around three sides of the coagulating basin and the coagulating basin is located within the space indicated by the iron railing shown on the picture. The basins together occupy a rectangular space approximately 135 ft. long by 70 ft. wide, and the center coagulating space is 84 ft. by 25 ft. The settling basins are about 19 ft. deep and the coagulating basin 16 ft. The tower shown is the coagulating portion of the building providing gravity feeds for the solutions used in the purification process.

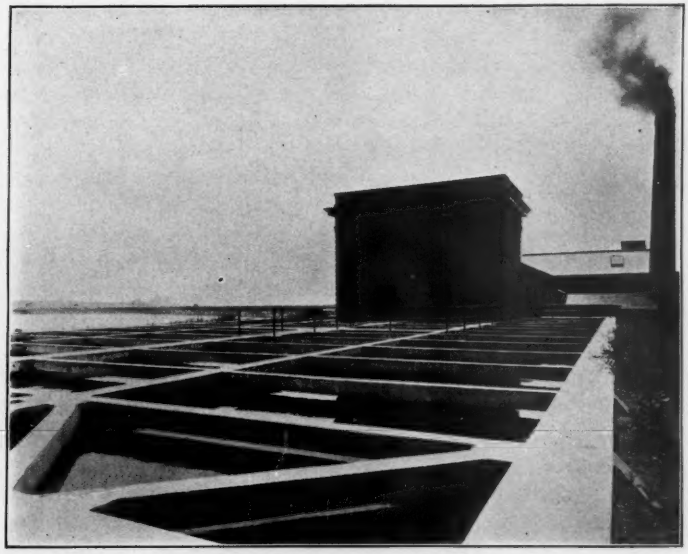

FIG. 1.

ARRANGEMENT OF SETTLING BASIN AND COAGULATING BASIN IN RELATION TO FILTERS.

FIG. 2.

COMPLETE SEDIMENTATION AND COAGULATING BASIN BEFORE SUPERSTRUCTURE WAS ERECTED.

Fig. 2, Plate I, shows the completed sedimentation and coagulating basins, filter tanks, clear well, and machinery room all enclosed before erection of buildings. The elevated structure shown above the basin contains the concrete storage tanks, four in number, for the sulphate of alumina and hypochlorite of lime solutions. The building in the background is the pumping station, and the sheet of water shown is one of the supplies of the water works, in fact, the receiving basin or impounded reservoir from which the low-service pumps supplying the filters take their suction.

As you probably know, Rhode Island has few hills and consequently a limited watershed, so that large impounded areas are used to provide the supply for Newport. These supplies are connected together, and to the receiving reservoir shown adjacent to the pumping station. A special pumping station is in use occasionally to force the water from one of these reservoirs to the receiving basin because of an intervening hill. Newport's water supply is carefully guarded against pollution, large areas of water-shed being owned by the company. From the viewpoint of filtration, however, this is a difficult water to handle, as most of the supply is high in color Portions of the supply differ radically from each other in character. All of it is low in alkalinity, and algal growths at certain times prevail.

The report of the State Board of Health for July, 1910, states that considerable micro-organisms were present, including desmids, protozoa and nostoc, crustaceans and amorphous matter. These continued through August, while the report of November includes asterionella, pediastrum, and scenedesmus. At that time, November 15, 1910, the report shows the raw applied water to have a color of 43 and 330 bacteria per cubic centimeter, and the treated filtered water to be 5 in color and had no bacteria per cubic centimeter.

Our own chemist, Mr. Nichol, now in that neighborhood, writes me that he finds scytomena in quantities clinging to the filter walls.

These difficulties were foreseen and influenced the design, Dr. J. L. Leal, who acted as adviser to the water works and supervised the design of the plant, wishing all the latitude possible to meet and remove these disadvantages.

Constructively, the plant is an excellent example of reinforced concrete; it might rather be described as concreted steel.

Fig. 1, Plate II, gives an idea of the very thin reinforced beams tying the open coagulating and sedimentation basins together in place of decks, and indicating the concrete flume opening through which the subsided water passes to the coagulating basin and then to the filters by gravity. There are 1 640 cubic yards of concrete of the proportion 1:2:4, and 76 tons of corrugated type D steel bars used, the steel being approximately 0.7 per cent. of the bulk of the concrete. The capacity of the sedimentation basin is 750 000 gallons, or three hours' continuous subsidence at the normal filtering value of 6 000 000 United States gallons in twenty-four hours. In addition, the capacity of the coagulating basin is 250 000 gallons, or a period of one hour's coagulation; the total capacity for subsidence and coagulation is therefore 1 000 000 gallons, or a period of four hours from the time the water enters the settling basin until it reaches the influent flume to the filters.

Within the space connecting the pumping station with the new filter building is arranged the low-service machinery rooms.

This room (Fig. 2, Plate II) is on a level with the old pump room, elevation 14.43, about 7 ft. below the operating floor of the filter house, elevation 21.25, so that it is easily reached by the engineer in charge, and also forms the entrance to the filter house. In this machinery room are located two 6 000 000-gallon centrifugal pumps, each direct connected to vertical Sturtevant engines, and these pumps supply the sedimentation basins with the water to be purified, pumping first to two large aërating devices, one on either side of the two settling basins, and superimposed above them and partly supported on the filter deck. In this room also is located the blower furnishing air to assist in washing the filters, and the two cast-iron float tanks with levers operating the balanced valves on the steam supply to the engines; these float tanks are connected with the level of the water in the coagulating basin so that the pumps increase or diminish the supply automatically. And here, too, is located the testing table disclosing the water passing from the filters, and the raw water as well

At times considerable odor exists in the raw supply, rendering a very thorough aëration necessary before it passes to the filters.

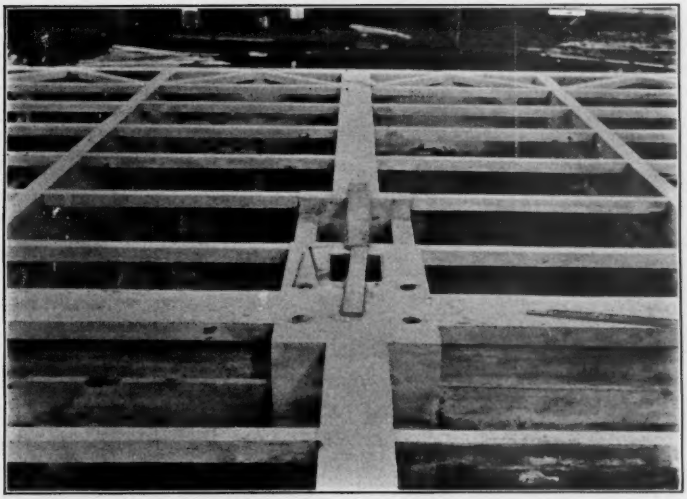

FIG. 1.
SURFACE OF COAGULATION BASIN SHOWING FLUME ENTRANCE.

FIG. 2.
LOW-SERVICE PUMPS.

The aërating devices (Fig. 1, Plate III) are, I think, novel and certainly have proven successful in the results obtained. They consist of substantially two large concrete boxes, each with two sides or slabs converging to a common center. On these slabs rest certain cast-iron sections about 2 in square. These sections are ridged in such a manner that when bolted together, covering the entire surface, the whole presents a series of channels abutting one against the other and forcing the incoming water to take a tortuous tangential direction, and making a multiplicity of miniature water falls over which the water dashes, reaching the channel at the bottom of the converging slabs thoroughly aërated and without further cost than the extra lift of about 4 ft. implies. The collecting channel then permits the water to pass into the settling basins and eventually to and through the filters, passing through Weston controllers located in the pipe gallery, finally to the clear water well under the filter house whence the high-service pump lifts it to the consumer.

The pipe gallery is lighted by electricity, is spacious and easily entered by a door leading from the machinery room.

Fig. 2, Plate III, shows the operating floor above the pipe gallery before the building was erected. The filter bed openings and the line of the building is also indicated. On the right is located one of the aërators.

The same space is shown in Fig. 1. Plate IV, after the erection of the building and installation of the operating tables. Here the laboratory room is located. At the upper end of the operating gallery, and beyond the laboratory, is the storage space. Storage and mixing tanks with agitators are arranged in a gallery elevated above the main floor, while on the main floor are located the orifice and regulating devices for the feeding of coagulant and hypochlorite solution.

On the operating floor, the loss of head gages are installed adjacent to the operating tables. These tables are constructed of black slate, and the indicators and valve handles are nickel plate, the whole adding to the appearance of the gallery.

The filter house proper opens into the coagulant tower located just above the end wall of the coagulating basin (Fig. 2, Plate IV). In this tower are arranged all the coagulant devices; the upper

portion of the tower or gallery contains the two hypochlorite of lime tanks and the two sulphate of alumina tanks, all four of reinforced concrete, each 7 by 7 by 5 inside. By means of a hoist and bucket the sulphate of alumina is lifted in measured quantity and laid upon the racks and water sprayed upon it until dissolved, and the concrete storage tank filled to a prearranged point, whereupon the water automatically shuts off, and the stored solution, 2 per cent. strength, is ready for use; this solution, kept in motion by agitators, then feeds into a porcelain-lined cast-iron orifice box located below and in measured quantity is introduced from there into the raw water at two points if required, namely, the suction of the centrifugal pumps and the influent flume to the coagulating basin. While the hypochlorite solution is also used and stored as a solution and fed through similar orifice feed boxes, the handling of the salt itself is somewhat different in order to get it into the storage tank with the least exposure. Superimposed above the concrete storage tanks are two cast-iron porcelain-lined mixing tanks with tight covers and equipped with agitators, revolving at a faster rate than is necessary for those used in the storage tanks.

The hypochlorite is placed in these mixing tanks and thoroughly agitated with a small stream of water passing in and out to the storage tank, the storage tank meanwhile slowly filling to the point required. The hypo. is thus kept in a sort of chyle or milky solution, gradually weakening in the mixer and passing to the storage tank where the slower moving agitator keeps it thoroughly mixed. Little or no odor is noticed around this process, the mixing occurring but once a day.

Preliminary operating by us soon established the fact that introducing the hypo. into the raw water had no apparent effect even when quantities sufficiently large to convey distinct odor of chlorine to the filtered water were used. No reduction of bacteria or color was apparent and no appreciable elimination of algæ was noticed.

When coagulation with sulphate of alumina was accomplished by its introduction as the water entered the settling basin, and the coagulated water was filtered in the usual manner so that perfectly clear water greatly reduced in bacteria passed into the clear water

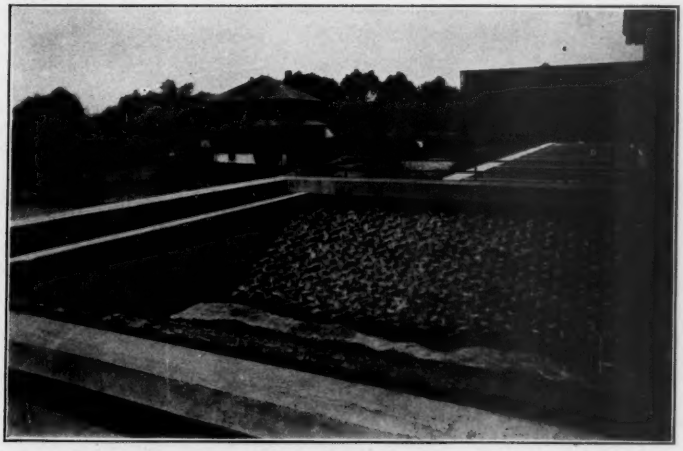

FIG. 1.
AËRATING DEVICES.

FIG. 2.
FILTER OPERATING FLOOR AND FILTER BEDS.

FIG. 1.
OPERATING FLOOR.

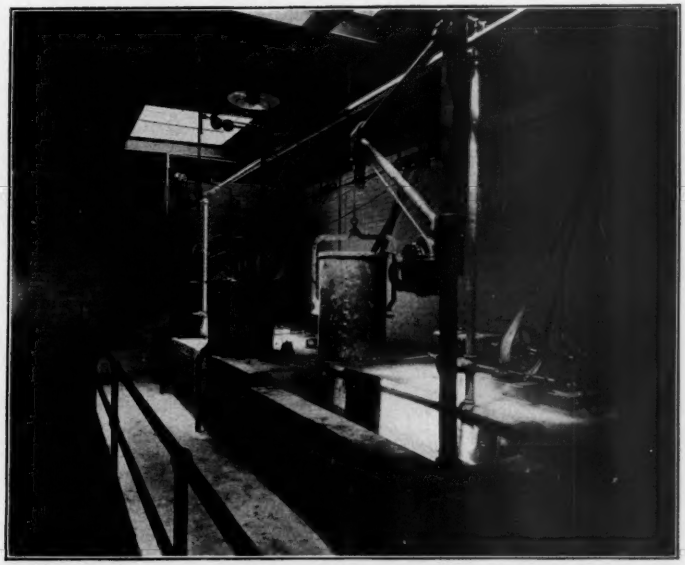

FIG. 2.
COAGULANT, HYPO-STORAGE, AND MIXING TANK.

well, and the hypo. solution in minute quantities was fed at a point in the clear well at the sump or suction to the high-service pumps, the desired result was attained and practically sterile clear bright filtered water was pumped to the consumer.

At the time the above-quoted State Board of Health analysis was made, November, 1910, one grain per gallon of sulphate of alumina was fed to the discharge of the low-service centrifugal pumps, and 0.5 parts per million of hypochlorite of lime were applied at the sump or outlet of the clear water well.

The capacity of the clear water well is 116 000 gallons, and covers the entire basement of the filter plant proper. These are six 1 000 000-gallon filters of the Continental air wash pattern, each discharging separately into it so that the one point where all the filtered water comes into intimate contact with all the hypo. fed through one connection is at the outlet of the basin where the high-service pumps take their suction.

The officers of the water works gave every assistance, and the thanks of the contractors are especially due Mr. E. W. Kent, chief engineer and superintendent, who supervised the construction for the Water Company, and under whose direction all the mains exterior to the building were laid and all the excavation accomplished.

WATER CONSUMPTION AND STATISTICS RELATING THERETO.

BY EDWARD S. COLE, CONSULTING ENGINEER, NEW YORK.

[*Read March 9, 1910.*]

It is not my purpose to discuss the broad subject of water consumption, but rather to plead for a more rational method of reporting the statistics of water use in American cities.

The need of better data has been appreciated keenly by all who are interested in the improvement of American works along lines of economy and efficiency. We in this country are very late to take up the conservation of our water supplies, however advanced we consider ourselves in other fields. Without doubt we must sooner or later find ourselves obliged to practice economy in water-works matters just as have our English cousins, and the certainty that this change is coming is the chief argument in favor of better water supply statistics, such as will give us the much-needed measure of relative economy.

Our cities may be wasteful or economical in water use, but there is no competent evidence of the fact available to-day. Per capita consumption as we have it is of little or no value to the water-works man, whether he be interested in the operation of old works or the design of new ones, for the excellent reason that it has been our time-honored custom to lump business and domestic consumption. Obviously it is futile to compare total per capita ratio of consumption without first excluding business use. It needs no argument to show that "business use" bears no rational relation either to population or to anything else. It is an independent variable with which it is impossible to solve the great problem of reasonable use in American cities. In the name of common sense let us eliminate it!

We are all familiar with examples of variable use, for we have the suburban town with little or no such use and the mill town

with a disproportionately large amount drawn for manufacturing purposes.

It is plain that we must separate business and domestic consumption if we would make comparisons. Even in our large cities, business use varies greatly, though but few reliable estimates of it have been made; probably a variation of two hundred per cent. is quite possible. The twenty-five gallons per capita estimated by Mr. Brackett as used for business purposes in Boston is hardly a criterion for similar use in New York, Pittsburgh, Buffalo, or Chicago.

Right here let me say that we cannot be too cautious in reporting the total amount drawn for business purposes. Even when entirely supplied through meters we must accept the figures subject to an increase because of the widespread fondness of the American manufacturer for getting ahead of the local water department. That large meters *are* by-passed, or water drawn from fire services or other unmetered connections, is beyond question and to an extent not realized by many superintendents. Speaking from a personal knowledge gained in making district tests in many cities during the past ten years, I do not hesitate to say that this sort of thing is responsible for much of the apparent unreasonableness in reported statistics as well as for great financial losses to city revenues.

Incidentally let me add that such losses need not continue, for there are several well-known means for detecting them. Is it not possible that a few of our cities which enjoy the distinction of reporting a low per capita rate are more indebted to a fortunate combination of circumstances, such as a large tenement-house population and non-water-using mills, than to unusual efficiency of management?

How often have we as outsiders misjudged a city reporting an apparently excessive total rate, when as a matter of fact there are special large business or other uses which justify that rate.

As to domestic consumption we also find a variation, but it seems to bear a more or less rational relation to the character of the consumers.

Here we find according to published statistics of metered consumption a range from ten or twelve gallons per capita daily for

the tenement-house dwellers with their scanty supply of fixtures and unsanitary habits of living, to eighty or ninety gallons per capita for the finest residences and city apartment houses.

Obviously it would be fair to divide domestic use according to three general classes representing the highest, middle, and lowest rate of use without involving unnecessary complication. Such a classification would throw a flood of light upon the whole matter of relative use and waste.

First of all, we should be careful in reporting the total yearly consumption. Too often this is based upon plunger displacement without any correction for slippage. Where such allowance is made it would be well to report the method by which the actual net pumpage has been determined. This information would give to the figures a value which they do not now possess.

We now have the following standard form as recommended by this Association.

(1) Population { Total. / On line of pipe. / Supplied.

(2) Total consumption for year.

(3) Quantity passed through meters and per cent. of total.

(4) Total number of meters and per cent. of services metered.

(5) Average consumption daily. { Total. / Per inhabitant. / Per consumer. / Per tap.

In order to bring the matter definitely before the Association, the following form which seems to represent the minimum requirements is suggested.

BUSINESS AND PUBLIC USE.

(1) Business and public use by meters.
(2) Business and public use, unmetered (estimated).
(3) Business and public use, per capita.

DOMESTIC USE.

First-class dwellings, hotels and apartment houses.
- Gallons metered to this class.
- Estimated population metered of this class.
- Per capita metered daily of this class.
- Estimated population of this class.
- Estimated use of entire city, metered and unmetered, of this class, based upon above rate shown by meters.

Middle-class dwellings.
- Gallons metered to this class.
- Estimated population metered of this class.
- Per capita metered daily of this class.
- Estimated population of this class.
- Estimated use of entire city of this class.

Lowest-class dwellings, with scanty plumbing.
- Gallons metered to this class.
- Estimated population metered of this class.
- Per capita metered daily of this class.
- Estimated population of this class.
- Estimated use of entire city of this class.

DISCUSSION.

MR. LEONARD METCALF.* It seems to me that Mr. Cole's suggestion is a very good one indeed. It is so plainly true that it hardly needs anything to be said in favor of it. Of course there is a practical difficulty in gathering the statistics which he suggests, but in a system which is thoroughly metered it ought to be possible to do it, and it seems to me that the cost of obtaining the information is so small that it might well be incurred. It does seem to me that it might be advantageous for the Association to give consideration to that fact in the form of statistics which has been prepared for general use, so that we might at all events obtain such additional information along these lines as is possible.

MR. ELBERT E. LOCHRIDGE.† Mr. President, I have been very much interested in Mr. Cole's paper, especially in the part re-

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.
† Chief Engineer, Water Department, Springfield, Mass.

lating to business uses of water. I think, as Mr. Cole does, that one city can hardly be judged in comparison with another as to the use of water, for we may have a city which is well metered with a comparatively high consumption per capita, and another, with perhaps not more than forty per cent. of that amount. If we were able to designate, as of course is possible in some systems, what the water could be used for, we would largely eliminate some of the business uses, or at least show what these uses were and what they amounted to as a business proposition.

MR. GEORGE A. STACY.* I think Mr. Cole has opened up a new line of thought, or, rather, he has expressed the thought in a way in which it has not been expressed here before, which is of considerable value. It seems to me that there is a great lack of information in regard to it. It seems perfectly natural and perfectly right, if we are going to state the consumption per consumer, to state it as nearly correctly as possible. That is very difficult to do when we mix up other uses with the domestic use, as we have done in the past. It seems to me that this will be a long road to travel, if we are going to see it through.

THE PRESIDENT. I think you might find it interesting to study the water consumption in the two cities of New Bedford and Fall River. They are very similar in the character of their population, both being cotton mill cities. In Fall River they have an abundant supply of water for their boilers, and do not use the city water. In New Bedford I think nearly all the water for condensing purposes is taken from the city mains, and, of course, the consumption per capita in New Bedford is from two to three times what it is in Fall River. The reason that is generally given to account for that is that Fall River is a metered city and New Bedford is not, but I think that is not the true explanation.

MR. GEORGE A. CARPENTER.† Mr. Cole has alluded in a modest way to a fact which is of much greater importance than he has given to it. We are in the habit of reporting our conclusions regarding the work of our pumping stations to a considerable degree of minuteness. We estimate carefully the amount of coal consumed, the amount of money expended in various ways, and then

* Superintendent Water Works, Marlboro, Mass.
† City Engineer, Pawtucket, R. I.

as a basis for deciding upon the effective work of our systems we depend upon an altogether unknown quantity, the amount of water sent out by our pumps. We take for that factor the plunger displacement with, perhaps, a suggested amount of slip, amounting to something like 3 or 4 per cent.; because the engineer hardly cares to admit that his pump is giving an excessive amount of slip.

Now, I know that operating engineers will take exception to this statement, but I firmly believe, from what information I have been able to gather, that the amount of slip in a large majority of pumps in our pumping stations is an entirely unknown quantity; and yet we base all our calculations upon that quantity.

In an investigation made a few years ago, in regard to the consumption in a city which was rated by plunger displacement at about ninety gallons per capita, — not a large per capita consumption for our American cities, — I made a complete investigation, taking as a basis of the population the census returns of the enumerators at Washington, which divide a city into smaller districts than can usually be obtained from the reported returns, and taking for the water consumption of those same districts the meter records of the department. In this city where the consumption by plunger displacement and by the figures reported was upwards of 90 gal. per capita, the domestic consumption, when applied to purely domestic uses, was not over 20 gal. per capita, and the total metered consumption where factories and domestic consumers were both metered, was only about 40 gal. per capita. I am positive that the remaining 50 per cent. cannot in any way be accounted for by leaks or waste. In confirmation of that, a large section of this city was later supplied with a meter on the 12-in. main delivering water to that section, and the consumption was found to be practically what had been computed for it, without any addition of 40 or 50 per cent. for waste. It therefore seems to me decidedly important to measure the water as it goes from our pumps by some form of meter, for then we will have a better foundation upon which to base our future calculations.

Mr. Frank C. Kimball.* I had occasion to look into a plant this summer, where the superintendent instead of using the

* Civil Engineer. Boston. Mass.

plunger displacement to calculate the quantity of water which was pumped, shut the inlet gate into the pump well about once a month and pumped a given number of revolutions, and, noting the depth to which he drew the water, figured his plunger displacement from that, until he again tested it.

There were three pumps in that plant, and one of those pumps showed about 6 per cent., while one of the others showed something like 18 per cent. discrepancy between the actual pumpage as calculated from the well displacement and the plunger displacement. For some years now he has used that method, and does not enter his record as so much displacement less per cent. of slip, but enters it direct by dividing the displacement in his well by the number of revolutions. Wherever pumping is done from a well or a gallery, where the water can be shut off even for a limited time, say five minutes, this method will give you a very much better result than mere plunger displacement.

I can remember that the first time I had to calculate the discharge of a pump I was told to use 2 per cent. for the slip, as that would cover everything. I took occasion on that same plant, a little while later, to shut down the discharge gate, and pumped against it to see how many revolutions I could get out of the pump. Of course that is not an accurate method of determining the slip, by any means, but it is very much better than to assume 2 per cent., especially as I got about 7.5 per cent. out of that pump in that way.

MR. JOHNSON. I can offer some further testimony, perhaps, on the line suggested by Mr. Carpenter. This last summer I have had occasion to try to reconcile the meter readings, where a meter was placed on a force main, with the records of the displacement of the pump. I was very much surprised to find that the meter would sometimes record 30 per cent. less than the pump for a period, say, of several weeks, then it would be practically the same and then, perhaps, for two or three weeks it would be 20 per cent. less than the plunger displacement. We finally notified the makers of the meter and had them send a man up to find what was the trouble with it. He failed to find any trouble with the meter, and then I sent a man out to study the pump records day by day. He stayed in the pumping station watching the meter and the counter, and as a

result we found that the trouble was entirely in the pump. We now, after having made some changes in the pump, have the readings practically in agreement, — perhaps one or two per cent. difference. Sometimes there would be a chip under one of the valves of the pump, and sometimes something else would happen, but in every case where there was a great difference there was something the matter with the pump. I was impressed with the fact very forcibly that it was not only essential to test the pump occasionally, but that it is decidedly essential to have a meter on the force main, in order to get any accurate results, — anyway with this kind of pump. This is not intended as an advertisement for meters, but I firmly believe that a meter is an excellent thing in my own pumping station.

Mr. Allen Hazen.* I have tried the experiment which Mr. Kimball described of closing the outlet of the pump and seeing how fast it would go, frequently; and I have almost always learned something from the experiment. In one case I remember a pump driven by water power which had been in use a good many years, and which was the main stand-by of a high-service system. Other pumps had been put in to help it out from time to time, but this old pump was the main stand-by. We needed to know how much water was being used, so one day I took the responsibility of closing the valve on the outlet. The pump never hesitated.

Mr. Robert S. Weston.† I was in Cincinnati a few years ago, and they told me a story about the old pumping station there which may be of interest in this connection. They had three very old pumps at the time the pumping station was dismantled, and on one occasion they stopped one of these three pumps, and no water ran into the reservoir with the other two pumps working.

Mr. John C. Chase.‡ I may add a word of testimony as to the testing of a pump for slip. Some fifteen or twenty experiments, carried on over a period of about six months, showed that only from 83 to 90 per cent. of the measured capacity of the pumps was obtained. The 90 per cent. was when a new plunger had been put in and it was in first-class condition. Our experience in pump-

* Civil Engineer, New York City.
† Sanitary Expert, Boston, Mass.
‡ Consulting Engineer, Derry Village, N. H.

ing against closed valves was practically the same as that of Mr. Kimball and Mr. Hazen.

MR. W. F. SULLIVAN.* In Nashua we are separating the amount of water used by large manufacturing corporations and railroads from the rest of the consumption, and we find that it represents about forty gallons per capita out of the total.

MR. SAMUEL A. AGNEW.† A number of years ago I wrote a paper on what my pumps were doing at Scituate,‡ and I estimated that a certain amount of water was being pumped, subtracting 5 per cent. for slip. Since then I have had occasion to question the amount that I gave. In the summer there is a time when we use a great deal of water in the town, and I find I am not pumping as much water as I seem to in winter. I was wondering whether I could get any information as to the ratio between the vacuum and the amount of water a pump will deliver. I can shut up the gate on the suction and secure 28 in.of vacuum. I can open that gate in the middle of the summer, and I can make 26 in. That is the amount of vacuum I work against. I was wondering whether I could get any information as to the ratio of the amount of water pumped to the amount of vacuum. Possibly somebody can tell me. For instance, we have one pump which will deliver 160 gal. per minute at about 15 in. of vacuum, and I was wondering how much that pump would deliver at 26 in.

MR. HAYES.§ What is your source of supply?

MR. AGNEW. Driven wells, 2.5 in. in diameter.

MR. HAYES. What is the difference in their depth?

MR. AGNEW. I don't know anything about the depth of them. It would be the same if we had an open well, if we had 26 in. of vacuum. I was wondering how much water these pumps would deliver under 26 in. of vacuum.

MR. HAYES. I can't answer the question offhand, but I do know of an experience they had over in Somerville, at the New England Dressed Meat and Wool Company. They put in 118 wells some 2 and some 2½-in. and with them all on we could not get as much water as we did after we cut them down to 89. That

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.
† Superintendent of Water Works, North Scituate, Mass.
‡ JOURNAL N. E. W. W. A., Vol. XX, p. 330.
§ F. H. Hayes Machinery Company.

is to say, we got better vacuum with the 89 than we did with the 118 from the fact that we were getting air. But to answer Mr. Agnew's question direct, how much water a 2½-in. driven well will give with 26 in. of vacuum, I cannot.

MR. AGNEW. I was not asking how much the individual well would deliver. We have 40 of those wells, and it stands to reason that the pump, no matter in what condition it is, will not deliver as much water under 26 in. of vacuum as it will under, say, 10 or 15 in. I know it will not deliver a drop with the suction gate shut, and then I can make but 28 in. Now, there is 2 in. leeway. It is sometimes almost terrifying to go into the pumping station while the pump is working under those conditions. It is impossible to keep bearings tight enough so but what they will bang and rattle, and yet have them loose enough so they will not heat.

MR. HAYES. You probably don't get solid water, but get some air. Do you take your calculations from your revolution counter against the water you pump?

MR. AGNEW. I did that once; I don't do it now.

WATER HAMMER.

TOPICAL DISCUSSION.

[November 9, 1910.]

MR. E. E. LOCHRIDGE.* I want to bring up for discussion the question of the use of water in direct pressure elevators where large amounts are used and paid for under the regular rates. Any water which is shut off quickly will develop a water ram, which will undoubtedly have some effect on the stability of the pipe. I do not believe that most of us realize how enormous a water ram can be. We ordinarily think of adding, perhaps, 50 per cent., or in some cases 100 per cent., to the pressure which we are working under, for the water ram. Recent studies have led me to believe that water ram can be considerably greater than that. This is a point to be taken into consideration in determining the thickness of the larger pipes in our distribution system.

The use of water elevators I know is allowed in some cities and is not allowed in others. It is getting to be an important question with us in Springfield, and I would like to get the ideas of different superintendents and engineers here on the subject, together with the experience which some of the cities have had with it, both those who have permitted the use and do not now, and those who now permit the use of water elevators and believe that it offers a good market for the water.

MR. JOHN H. FLYNN.† I think the best way to avoid the water hammer is to have such machinery as will not produce water hammer. If you let everybody put in elevators as they see fit, and run them as they see fit, you must expect to get water hammer. Water-works superintendents should not accept a water elevator system unless it is free from water hammer or any water troubles, and there is no trouble about getting such a system.

MR. WILLIAM F. SULLIVAN.‡ I will say that we have a great many railroad standpipes in Nashua, and every time a locomotive

* Chief Engineer, Water Works, Springfield, Mass.
† Deputy Superintendent, Water Department, Boston, Mass.
‡ Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

takes water we get what we call a great *jab* on our indicator card; and when there are four or five standpipes closed almost simultaneously, we get an extraordinary *jab*. We are trying to solve the difficulty, and have put it up to the railroad that they ought to erect tanks into which we could feed water, so that they could get these large quantities of water without danger of water hammer. The railroad people are around asking us to put in one of those large 4 000-gal. tanks in about a minute. I think the water ram or water hammer is going to be increased unless they have some other system than they have in the present standpipe arrangement.

With regard to elevators, we find the same trouble which Mr. Lochridge finds in Springfield; but we have meters on, and there are 4- or 6-in. pipes to them, and the water is taken direct and wasted into the sewer, and we get our money for it.

Mr. Walter H. Richards.* With respect to the elevator question and direct connected elevators, it occurs to me that possibly the water may be too valuable to be used in that way, particularly where there is a low or a moderate pressure, for with such a pressure of course they have to use a great deal of water. It seems to me, if the water rates are high enough and you put on meters, people would get tired of using the water before long, because the water is not applied in an economical manner, and its use would be too expensive.

Mr. George Cassell.† I have had a slight experience in regard to water ram in Chelsea, and I have been unable to find out from anybody whom I have approached what the cause of it was. Some months ago, through the interest taken by the insurance men, we put in a special high-service gravity system for sprinklers and no other purpose in the manufacturing establishments in the eastern section of the city, as the pressure we had up to this time did not satisfy them. When we had got it installed and in operation we found that the pressure at the end of the line in the eastern section of the city on the sprinkler system in a very large manufacturing concern was 108 lb. static pressure. A short time afterwards I had a telephone message from that company stating that the pressure was so great that it had started some

* Engineer Water Department, New London, Conn.
† Superintendent Water Works, Chelsea, Mass.

of the sprinkler heads, and they would like to know if we could not do something to reduce the pressure.

A short time ago they rang me up again, and they were very much excited. They said that again sprinkler heads had gone because the water had jumped from 108 to 130 lb. I told them that we had nothing to do with it; that if there was anything to cause water ram it must be on their premises. I later talked with the engineer of this company, who is responsible for the installation of the sprinkler system and of the fire system which is connected with it, and asked him if he had been able to find out what caused the ram. He said that he had not. Then I asked him what sort of sprinkler heads he had that went off at 130 lb., and he told me the names of the different sprinklers. I won't mention them, because I am not here to advertise any sprinkler heads, but I took the matter up in regard to the number of pounds pressure that a sprinkler head would stand, and I found out that it was so much greater than the pressure they had that I made up my mind that the sprinkler heads that went off were so antiquated that they had better change them; and they have changed them, and since then we haven't had any trouble. But I haven't as yet found out what caused the water ram.

MR. FRANK C. KIMBALL.* I would like to ask Mr. Cassell if there was a meter on the pipe that ran into that mill, — on the fire pipe.

MR. CASSELL. No, sir.

MR. KIMBALL. Possibly if there was a meter on there, — I do not know the place, so this is entirely impersonal and only drawn out as the result of some experience I have had in other places, — the meter might have shown some draft of water about the time that this water ram occurred.

MR. CASSELL. I am going to answer Mr. Kimball's suggestion in the way it was put to me once: "Why, you don't doubt the honesty of a manufacturer, do you?"

MR. KIMBALL. I never did in my life, but I have metered every fire service that I have had anything to do with running into a mill for the past ten years, and I find that from the income point of view it is the best thing to do.

* Civil Engineer, Boston, Mass.

MR. CASSELL. I should be very glad to install meters, but, the moment you begin to talk about that, the first question asked is, How much is it going to cost? — and when you tell them, they throw up both hands. The consequence is that the powers that be seem to decide with the people as against the practical men, and consequently we are considered antiquated in not installing something which would protect the city, up to the present time. But I think if they continue to place the burden upon the water departments the water superintendents will have to take some summary measures to protect themselves from criticism in the future.

MR. LOCHRIDGE. Are there any superintendents or engineers present representing systems which have a pressure sufficient to operate elevators directly, who have eliminated the use of water elevators, and if so, why? I would like to have them tell what their experience has been along that line. I believe one of the speakers has referred to an indirect system, — that is, where the elevator is raised hydraulically, but where the power does not come directly from the main. If the water is taken from the main, and enough taken to operate an elevator, when it is shut off there must be some water ram, in any system which could be devised.

MR. KIMBALL. In one company I had at one time something like thirty or forty hydraulic elevators. The water hammer caused by those was such that by a recording gage we could never tell within forty or fifty pounds what the normal pressure on our pipes was. A large part of that we finally overcame by insisting on an adequate air chamber placed on the pipes to take off part of the shock. A little later we got rid of nearly all of these hydraulic elevators, simply because the Electric Light and Power Company came into the field and wanted the business and we found that we could not compete with them at ten cents per thousand gallons; so we got rid of all the elevators. We were glad later that we did. I think that except at a price fully as great as, if not greater than, the ordinary price for water you cannot afford to have elevators connected directly with your mains. You cannot tell what is happening. You may have a break and you will not know what caused it. It may be a mile or two away from an elevator. I have an idea that elevators have a good deal to do with breaks on mains, when they are directly connected.

MR. JOHN J. KIRKPATRICK.* Mr. Lochridge is not the only one who has had trouble with water hammer. I think we have all had some. I want to state a little experience we had. We have one building eight stories in height on our main street that we furnish with water for elevator purposes direct to their piston during the day only, because at night they run a steam plant to light the building, and operate their pump from that. They have a little well or water gallery that they take the water from. Sometimes they are kind enough to close the valve between their elevator and our main, and sometimes they are not. We are very unfortunate in having the meter so placed that they have on one or two occasions blown the top off of it, when they had their pump going at 150 or 160 lb.

But those troubles are trifling compared with the troubles caused by the water hammer that we get from the American Street Car Sprinkling Company. There is a standpipe with a valve or gate that they draw from, within perhaps one thousand feet of where I live. I have a pressure gage at my house and sometimes it is amazing to watch the fluctuations of pressure. The normal pressure at my house is about fifty pounds, and I have seen it go at chain lightning speed up to one hundred and twenty. I wondered at first what caused it, but after I had run around the corner I found that our friends, the street-car sprinkler company, had been filling their tanks and pouring in about 3 800 gal. in two minutes.

MR. FLYNN. Over on Bay State Road there is a block of twenty houses. In eighteen of those houses there are elevators, and they have been in for twenty-five years, but I have never yet heard of a single complaint, either from the people who live on that side of the street or from those who live on the opposite side. We have only an 8-in. main on the street. It seems to me that if eighteen elevators can be put in twenty houses without causing any trouble, if other water-works superintendents will look after their elevators they will have no trouble.

MR. GEORGE E. WINSLOW.† It is a good while ago that I was the superintendent of our works, and it was a good while ago that

* Superintendent of Water Works, Holyoke, Mass.
† Waltham, Mass.

this work of which I am about to speak was done. They started putting elevators in Waltham, and I did not like the idea of their being operated by the valves which were ordinarily used, which would burst our cement pipe in about a week. So I recommended putting on a relief valve which would be as large as the tap or larger. On most of the elevators that were run with a 2-in. pipe, I would have a 2-in. relief valve, and have it set at ten pounds above the normal, so if the elevator were shut off quickly the pressure would escape through the relief.

I remember the case of one company which was going to put in an elevator, and I wanted to have a relief valve put on as usual, but they said there was no necessity for it as their valve was made in a V-shape, so that it will shut off the water gradually, so that it was impossible to create a water ram. Theoretically that was all right, but I had a relief valve put on nevertheless, and after that was put on I had them try it, stopping the elevator as quickly as possible. The relief valve opened all right, and the main pipe would have opened if it had not been for the relief valve.

When the Fitchburg Railroad did away with the pumping plant which supplied the locomotives with water, I was asked to connect up to their standpipes so that they could take water direct from our mains. I insisted on supplying them through 4-in. pipe from an 8-in. main, with a relief valve at least 3-in. in diameter as near the shut-off gate as possible. The railroad objected, but after waiting a year decided to comply with my conditions, and we made the connection. After this plant had been installed I went and saw its operation at the time the first locomotive was filled. The man shut off the gate at the ordinary rate that the railroad man does work of that kind, and the result was that the relief valve opened and ran for thirty seconds before it closed. That showed that there was a good deal of force or momentum to that water and it took quite a while for it to be overcome. We never have had a break in Waltham from the elevators or from the standpipes to my knowledge, and I was there for some years. The relief valve on the standpipe was set at ten pounds above the normal. I can see no other remedy, if you are going to have elevators or are going to close any valve suddenly, other than a relief valve.

MR. METCALF. It perhaps is worth while to call attention to the remarks of Mr. Flynn as showing the inapplicability of the Boston experience to Holyoke and Springfield conditions. It is merely indicative of the relative slowness of our motion here. If you have gone up in some of the Boston elevators you will find the explanation immediately.

MR. RICHARDS. At Springfield, as I understand, they have increased their pressure considerably, perhaps doubled the pressure, or something like that; but, as I understand, they use the same elevators they had before they increased the pressure, so that they are using an elevator pipe larger than is necessary; and they have increased the velocity of the water, of course, and hence they have increased the water ram. I would suggest that possibly that could be cured by closing the gate a little, or perhaps making the aperture that the water is supplied through a little smaller. I think very possibly that might remedy the difficulty.

THE USE OF WATER EJECTOR FOR TRANSPORTING SAND.

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[*Read September 22, 1910.*]

INTRODUCTION.

This paper is the outgrowth of certain experiments made by the Bureau of Filtration of the city of Pittsburg, under the direction of the writers, to determine the most economical method of transporting and washing dirty sand from the filter beds. Similar work had been done elsewhere, and the experiments hereinafter recorded were designed to supplement the then available information.

A summary of the data obtained in connection with these experiments, with reference to the other filtration works in this country, is also given, and it is hoped that with this information available in convenient shape for discussion, others may be induced to give their experiences with similar apparatus, for the benefit of the profession and all people interested and to make the history complete.

HISTORICAL.

London, 1886.

To Mr. William B. Bryan, chief engineer of the East Water Works Company, of London, England, must be given the credit for the first use of the ejector for transporting sand from filters, about 1886. The history of his attempts is given in Transactions of the American Society of Civil Engineers, Vol. LIII. He mentions one experiment in which sand was transported 700 ft. and lifted 12 ft. He also describes the method then in use (1903), which was a development of the above-mentioned experiments and is described as follows:*

* Trans. Am. Soc. C. E., Vol. LIII, p. 266.

"The dirty sand, instead of having to be wheeled a long distance out of the beds, as formerly, is merely wheeled into a cast-iron hopper, the water is turned on, under pressure, and left on until the whole of the dirty sand in the bed has been lifted out. It passes into one end of the rotary machine, and is also washed in transit. A little hydraulic engine, fed by pure filtered water, turns the arm inside the longitudinal cylinder, and the exhaust water flows into the hopper at the opposite end from the dirty sand, consequently there is always a current of water meeting the sand passing through the washer. The dirty sand overflows at one end, and, as the sand gets cleaner, it meets the cleaner water. The elevator drops it into a small iron receptacle and a $\frac{3}{8}$-in. jet of water throws the clean sand into an adjoining bed, the latter operation involving no loss of water whatever.

"In the original experiments, an unforeseen difficulty was met in connection with the suction pipe. This pipe was made somewhat coned, with the widest end of the cone dipping into the dirty sand, and the flow of water was so smooth that the organic matter in the sand formed a slime on the surface to a considerable distance, and prevented its efficient operation. Therefore the suction pipe was taken off and a straight pipe put in with the water entering a T-piece at the bottom, with holes drilled through so that it should enter four ways at once and the water jostle itself in all directions in passing up the pipe. No trouble has been experienced during the last seventeen years."

London, 1892.

In *Engineering* (London) for 1892, Vol. LIII, p. 621, an apparatus for washing sand from filters is described, which is something like that commonly used to-day. It was developed by Messrs. Hunter, Frazier, and Goodman, and consisted of a series of nine cast-iron hoppers 2 ft. 4 in. square and 2 ft. 2 in. high, with an ejector in the bottom of the hopper. The hoppers were arranged in series, the discharge from the first delivering into the top of the second and so on. The nozzles used were $\frac{3}{8}$ in. and $\frac{1}{2}$ in., and 3 cu. yd. per hour, with 5 000 gal. of water per cubic yard of sand, was given as the capacity of the machine.

Lawrence, 1895 and 1898.

The city of Lawrence, Mass., used a machine for washing the sand from its filter plant, which was the forerunner of the present

accepted type of sand ejector. This was suggested to the late Mr. A. H. Salisbury, superintendent, by Mr. Allen Hazen, who had seen a similar piece of apparatus at Hamburg, Germany. It is described as follows:*

"The bowls of the machine are four in number and are light sweepcastings made at a local foundry. The sand drops to the bottom of each bowl or hopper and is caught by an inflowing horizontal jet and carried across and upward through a 3-in. pipe into the next bowl. The fitting at the bottom of the hopper is a standard 3-in. cross, with a plug in the bottom for the purpose of cleaning. Into a bushing in the inlet end of the cross is placed a $1\frac{1}{2}$ in. pipe, to the end of which is attached a removable chilled-steel nozzle made from a piece of hexagonal rod. The nozzles in use have $\frac{5}{16}$-in. jets, although other sizes have been tried. At the outlet of the cross there is screwed a special 3 by 2 in. reducer, the small end of which is placed within the cross and is of bell shape in order to readily receive the mingled water and sand. These special fittings, which wear out continually, are made as required at the shop of the water department."

"The washer was built and erected early in 1895, and was first used on June 17. The cost of the patterns, castings, piping, lumber, and labor on the machine was about $150, and that of the concrete pavements and drains about $240, while the labor account of the department for setting up, etc., was about $150, making a total cost of $540."

"In an endeavor to find a more economical way of getting the sand to these washers than the method then in use (i. e., wheelbarrow work), one of the writers experimented with different arrangements for transporting the sand, and, in a short time, devised the following method, which was adopted. A traveling hopper, mounted upon a light frame of piping and placed at will wherever dirty sand is dumped, is fed from a 2-in. pipe from the main supply. Sand thrown into the hopper is carried by the entering water into and through a connecting length of 3-in. pipe to the main washer, where it is raised about 5 ft. into the first hopper of the machine. The nozzle of the traveling hopper is $\frac{1}{2}$ in. in diameter. The 3-in. pipe line varies in length from time to time, and is made of running lengths of pipe connected in such lengths as are necessary for a distance."

"This method has been in use since July, 1898, and has never failed carrying the sand to the washer from the most distant point required, about 200 ft., which is the maximum distance tried up to the present time. It appears that the sand has not only been

* Trans. Am. Soc. C. E., Vol. XLVI, p. 293.

washed more thoroughly since using this apparatus, due probably to a more complete mixing and scouring in the pipe line, but, also, there has been no apparent increase in the amount of water used, and, moreover, there has been a material reduction in the cost per yard. The ordinary water pressure at the machine, with everything running, is 63 lb. and at the hopper 56 lb."

It will be noted that the jets were horizontal in these washers and ejectors, thus differing from the practice at Hamburg and London.

Poughkeepsie, 1897.

This method of transportation seems to have been used previously (1897) by Mr. Charles E. Fowler, at Poughkeepsie, N. Y., who had successfully lifted sand 30 ft. and transported it 630 ft. through 4-in. cast-iron pipe.*

Albany, 1897.

The filtration works for Albany, N. Y., were designed in 1897–8, and provided for a sand-washing machine somewhat similar to that then in use at Lawrence, but having vertical jets as at Hamburg and which is described and illustrated in Transactions of the American Society of Civil Engineers, Vol. XLIII, p. 272. It consisted of five cast-iron hoppers arranged with vertical ejectors. The sand passed through each of the hoppers in succession, receiving an increment of clean water in each one, and discharging the dirty water over a depressed lip in each hopper to a drain. As far as the writers know, this is the only use of vertical jets in this country. An ejector has been used here since 1900 for transporting sand from piles to washer with great success.

Students of sand filtration in considering the various elements of cost entering into the operation of filters, have been impressed with the advantages which the use of ejectors for carrying the dirty sand from filters to the washers offered, and in the discussion of this paper, several suggested improvements along this line were made, many of which have since been adopted.

* Trans. Am. Soc. C. E., Vol. LIII, p. 250.

Pittsburg, 1900.

Along the same line, we find that in the designs for the Pittsburg Filtration Works of 1899–1901, by Mr. Allen Hazen, provision was made for the use of movable ejector hoppers in the filters and a system of pressure piping, hose and discharge piping, for the purpose of discharging to washers and from these into elevated wooden bins, from which it would be withdrawn to resand the filters.

This system was described and illustrated in *Engineering News*, February 13, 1902.

Philadelphia, 1901.

The Philadelphia Filtration Works were also designed about this time, and they provided for transportation of the dirty sand by ejector hoppers.

Some experiments were made to determine the best proportions of the apparatus, and the installation was designed on the basis of the results obtained. The results of these experiments were published in Transactions of the American Society of Civil Engineers, Vol. LVII, p. 386, and the first apparatus used is described in *Engineering Record*, Vol. XLVIII, p. 426, for October 10, 1903. Two cuts in this article show the portable ejector and washer designed for the Belmont filters. This washer was stated to have a capacity of 6.7 cu. yd. of sand per hour and to use 1,610 gal. per cu. yd. of sand, at a pressure of 60 lb. per square inch. Some experiments also were made at the Spring Garden Testing Station with an ejector for carrying washed sand back to the filter, but this was found to be unsatisfactory for various reasons and was abandoned.

Washington, 1902.

The success which had been attained by the use of this method of transportation induced the designers of the Washington filter plant to give it careful consideration and to experiment with various combinations, in an endeavor to find the most efficient apparatus.

These experiments are described and illustrated in the Trans-

actions of the American Society of Civil Engineers, Vol. LVII, p. 340, and the sand-carrying system was based upon their results. The ejector and washer used are shown upon pages 337 and 339 of that article. A 3-in. line of hose about 100 ft. long carries the discharge from movable ejectors to a 4-in. wrought-iron line along the walls of the filter and thus to the sand washers in the court. A similar method was also adopted at the Milford, Mass., New Haven, Conn., Providence, R. I., Peading, Pa., and Pittsburg, Pa., filters (1901) and also at a number of the smaller plants throughout the country.

It was found to have a distinct advantage, in that the sand was cleaned during its passage through the pipe and thus the number of hoppers required at the washing machine was diminished, with a consequent saving of wash water. Thus at Washington two hoppers were used at the machine, while at Pittsburg only one was required. At Pittsburg and New Haven, the washer ejector also serves to carry the sand back to a filter which is being resanded. A similar but modified form has recently been used at Washington, providing also for distributing the sand in water on the filter surface.

Pittsburg Experiments, 1905–6.

In the design of the sand-handling system for the first 46 filters for Pittsburg, the results of the Philadelphia experiments were available, and it was planned to make some additional ones along the same lines. These were carried out in the winter of 1905–6, and are summarized in Table 1. The $\frac{3}{4}$-in. nozzle with $1\frac{3}{8}$-in. throat 8 in. long gave the best results for 3-in. pipe 350 ft. long, and the $\frac{7}{8}$-in. nozzle with $1\frac{3}{8}$-in. throat 12-in. long gave best results with the 4-in. pipe 600 ft. long. On the basis of the above, the throats for the plant were ordered, as shown in Fig. 2, marked "S." Some tests were also made with hose, both laying out in lines and wrapped about a reel about 6 ft. in diameter. It was found that for the ordinary lengths used in filters, the increase of friction was not material.

When the results of the Washington experiments were published and the good effects of enlarging the throat in a Venturi fashion were realized, a further series of tests were decided upon. At

this time, the use of rifled pipe for conveying oil was brought to our attention and the lessened frictional resistances encountered in this work seemed promising for mingled sand and water.

TABLE 1.

RESULTS OF SAND EJECTOR EXPERIMENTS.

1905–6.

A.—3-in. hose and 3-in. pipe.

Experiment Number.	Diam. of Nozzle.	Diam. of Throat.	Length of Throat.	Dist. between N. and T.	Pressures.		Cu. Yd. Sand per Hour.	Gal. Water per Cu. Yd. Sand.	Per Cent. of Sand.	Remarks.
					Nozzle.	Discharge.				
	In.	In.	In.	In.						
9	¾	1⅜	15	1⅜	100	23	9.0	940	17.7	300 ft. of pipe plus 30 ft. of hose.
10	,,	,,	,,	1¼	100	21	6.93	1 020	16.5	do
11	,,	,,	,,	,,	100	20	8.17	930	17.8	do
12	,,	,,	,,	,,	100	20	7.81	930	17.8	do
13	,,	,,	14	,,	100	23	10.0	1 050	16.1	do
14	,,	,,	,,	,,	100	23	10.91	910	18.1	do
15	,,	,,	12	,,	100	23	10.29	1 030	16.4	do
16	,,	,,	10	,,	100	23	10.29	940	17.7	do
17	,,	,,	8	,,	100	23	12.00	820	19.8	do
18	,,	,,	6	,,	100	23	10.91	870	18.8	do
19	,,	,,	5	,,	100	23	10.29	930	17.8	do
24	,,	,,	5	,,	100	23	10.91	940	17.7	do
20	,,	,,	4	,,	100	23	10.91	870	18.8	do
21	,,	,,	3	,,	100	21	10.29	980	17.1	do
22	,,	,,	2	,,	100	19	8.17	1 160	14.8	do
23	,,	,,	1	,,	100	19	7.13	1 240	14.0	do
25	,,	,,	14	,,	100	27½	6.31	1 340	13.1	600 ft. of pipe plus 30 ft. of hose.
26	,,	,,	,,	,,	100	28	6.80	1 390	12.7	do
27	,,	,,	12	,,	100	27	6.20	1 520	11.7	do
28	,,	,,	,,	,,	100	27	6.13	1 540	11.6	do
29	,,	,,	10	,,	100	25	5.71	1 770	10.2	do
30	,,	,,	8	,,	100	25	5.85	1 630	10.9	do
40	,,	1¼	23	,,	70	21	4.13	1 890	9.6	do
39	,,	,,	,,	,,	80	23	4.92	1 680	10.7	do
38	,,	,,	,,	,,	90	26	5.63	1 485	12.0	do
36	,,	,,	,,	,,	100	27	7.20	1 300	13.4	do
41	,,	,,	,,	,,	100	27	16.66	1 500	11.9	do
37	,,	,,	,,	,,	120	27	7.12	1 390	12.7	do
31	⅞	1⅜	10	,,	100	31	6.42	1 720	10.5	do
32	,,	,,	,,	,,	100	30	5.00	2 160	8.5	do
33	,,	,,	,,	,,	120	35	5.07	3 080	6.1	do
34	,,	1¼	23	,,	100	30	6.31	1 700	10.6	do
35	,,	,,	,,	,,	120	35	6.00	1 830	9.3	do

TABLE 1.— *Continued.*

RESULTS OF SAND EJECTOR EXPERIMENTS.

1905–6.

B.— 3 in. hose and 4-in. pipe.

Experiment Number.	Diam. of Nozzle.	Diam. of Throat.	Length of Throat.	Dist. between N. and T.	Pressures.		Cu. Yd. Sand per Hour.	Gal. Water per Cu. Yd. Sand.	Per Cent. of Sand.	Remarks.
					Nozzle.	Discharge.				
	In.	In.	In.	In.						
42	1	$1\frac{3}{8}$	23	$1\frac{3}{4}$	97	30	10.90	1 510	11.8	516 ft. of pipe plus 30 ft. of hose.
43	"	"	"	"	97	30	11.80	1 470	12.0	do
44	"	$1\frac{1}{2}$	10	"	95	27	14.68	1 150	14.9	do
45	"	"	"	"	95	27	14.10	1 200	14.2	do
46	"	"	12	"	95	25	9.00	1 770	10.2	do
47	"	"	5	"	95	27	8.88	1 550	11.5	do
48	$\frac{7}{8}$	"	10	"	100	27	11.24	1 000	16.8	do
49	"	"	9	"	100	25	12.00	980	17.1	do
50	"	"	8	"	100	25	13.33	870	18.8	do
51	"	"	7	"	100	25	12.40	750	22 2	do
52	"	"	6	"	100	25	11.42	1 010	16.7	do
53	"	"	"	"	100	25	11.62	990	17.0	do
54	"	"	5	"	100	25	9.10	1 280	13.6	do
55	"	"	4	"	100	25	11.62	1 170	14.8	do
56	"	"	15	"	100	25	12.83	980	17.1	do
57	"	"	13	"	100	25	14.70	980	17.1	do
58	"	"	11	"	100	25	14.80	1 000	16.8	do
59	"	"	9	"	100	25	11.42	1 020	16.5	do
60	"	"	15	"	90	25	11.06	1 500	11.9	do
61	"	"	13	"	90	25	10.28	1 636	11.0	do
62	"	"	11	"	90	25	10.91	1 540	11.6	do
63	"	"	9	"	90	25	9.47	1 740	10.4	do

Therefore arrangements for making tests were made, the necessary apparatus secured, and a site, Brilliant Pumping Station, was selected, because of the water and sand being readily available. It is this set of experiments that this paper will present in detail.

Pittsburg Experiments, 1907–8.

The equipment consisted of the following apparatus arranged as shown on Fig. 1 and Plate I.

First. A standard cast-iron hopper and bottom used in sand washers at the filtration works. This is made in the form of a frustum of a pyramid; it is 5 ft. square on top and terminates in a

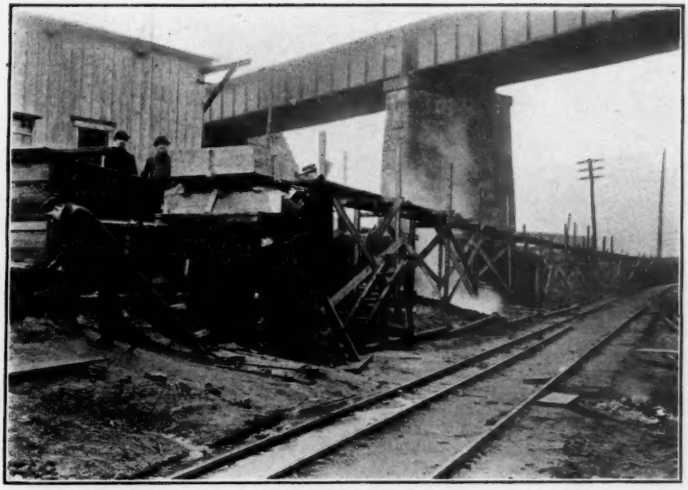


FIG. 1.

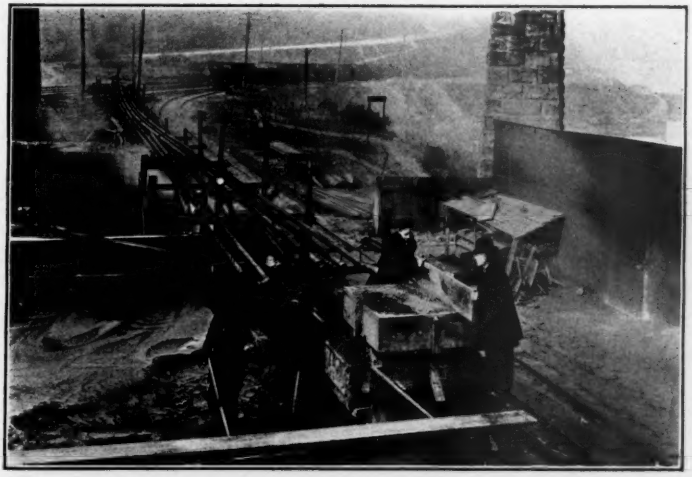


FIG. 2.

VIEWS OF EXPERIMENTAL SAND EJECTOR, AT BRILLIANT PUMPING STATION.

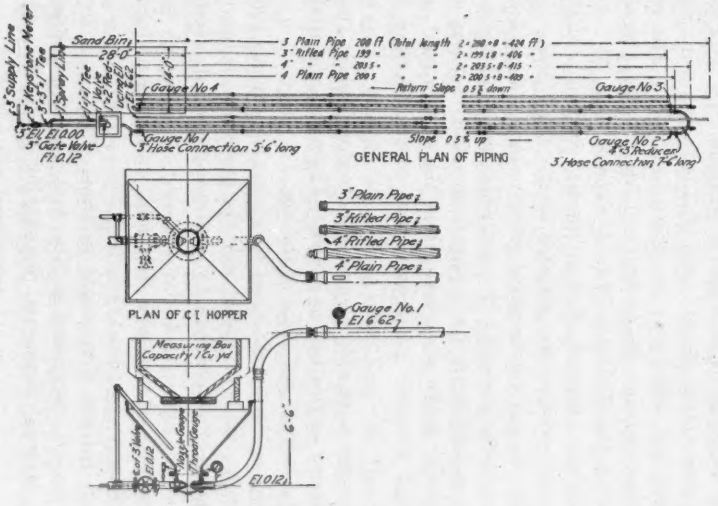
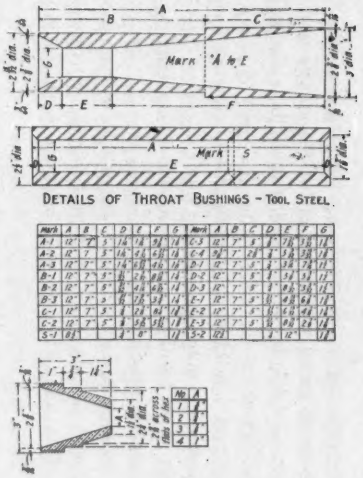

Sand Bin
28-0
3" Plain Pipe 200 ft (Total length 2 × 200 + 8 = 424 ft)
3" Rifled Pipe 199 " " " 2 × 199 + 8 = 406 "
4" " 203.5 " " " 2 × 203.5 + 8 = 415 "
4" Plain Pipe 200.5 " " " 2 × 200.5 + 8 = 409 "
Return Slope 0.5% down
Gauge No. 4
Gauge No. 3
Gauge No. 1
3" Hose Connection 5'6" long
Slope 0.5% up
Gauge No. 2
4"×3" Reducer
3" Hose Connection, 4'6" long
GENERAL PLAN OF PIPING
3" Plain Pipe
3" Rifled Pipe
4" Rifled Pipe
4" Plain Pipe
PLAN OF C.I. HOPPER
Gauge No. 1
Measuring Box Capacity 1 Cu. yd
Hose Connection
Elev. 12

FIG. 1.

SECTIONAL ELEVATION OF MEASURING BOX AND CAST-IRON HOPPER.



Mark	A	B	C	D	E	F	G	Mark	A	B	C	D	E	F	G
A-1	12"	7"	5"	1/4	1/2	3/4	1/4	C-3	12"	7"	5"	1"	1 1/2	1 3/4	1/4
A-2	12"	7"	5"	1/4	1/2	3/4	1/4	C-4	12"	7"	5"	1"	1 1/2	1 3/4	1/4
A-3	12"	7"	5"	1/4	1/2	3/4	1/4	D-1	12"	7"	5"	1"	1 1/2	1 3/4	1/4
B-1	12"	7"	5"	1/4	1/2	3/4	1/4	D-2	12"	7"	5"	1"	1 1/2	1 3/4	1/4
B-2	12"	7"	5"	1/4	1/2	3/4	1/4	D-3	12"	7"	5"	1"	1 1/2	1 3/4	1/4
B-3	12"	7"	5"	1/4	1/2	3/4	1/4	E-1	12"	7"	5"	1"	1 1/2	1 3/4	1/4
C-1	12"	7"	5"	1/4	1/2	3/4	1/4	E-2	12"	7"	5"	1"	1 1/2	1 3/4	1/4
C-2	12"	7"	5"	1/4	1/2	3/4	1/4	E-3	12"	7"	5"	1"	1 1/2	1 3/4	1/4
S-1	8"			1/4	1/2	3/4	1/4	S-2	12"			1"	1 1/2	1 3/4	1/4

FIG. 2.

DETAILS OF THROAT BUSHINGS AND NOZZLES.

12-in. diameter opening, having a flange for attaching the bottom piece. The bottom piece has openings for the nozzle and throat pieces, an opening for a water jet, and a hand hole for adjusting the nozzle and throat.

Second. A set of 4 nozzles, having openings varying from $\frac{5}{8}$ in. to 1 in. These were made of brass.

Third. A set of 18 throats having various dimensions, as shown in Fig. 2; all made of tool steel.

Fourth. A measuring box of wood, carried by the hopper walls and provided with a slide in the bottom to drop the contents into the hopper. This box, when leveled off flush with the top, contained 1 cu. yd.

Fifth. A short piece of $3\frac{1}{8}$-in. internal diameter, flexible hose, provided with couplings on each end to connect with the pipe.

Sixth. Approximately 400 ft. each of 3-in. plain, 3-in. rifled, 4-in. plain, and 4-in. rifled pipe, as shown in Fig. 1. The rifled pipe was secured through the courtesy of Mr. Taylor Alderdice, vice-president of the National Tube Company, and Mr. J. B. Isaacs, consulting engineer, Union Pacific System, Southern Pacific Company, who is the patentee of the rifled pipe.

Seventh. Various gages for reading pressures and glass cylinders to observe transportation effect of mixed water and sand in pipe.

The water was supplied to the hopper from a 3-in. cast-iron pipe, connected directly to the force main from the station, and, after passing through a meter, its pressure was controlled by a 3-in. valve.

Sand was secured from a bin alongside the hopper and the ejected sand was returned to this bin, as shown. The water was drained off through the bottom and sides of the bin.

The pressure on the nozzle could be varied from 60 to 120 lb. by manipulating the 3-in. valve, and the pressures or heads at various points were determined by pressure gages, all carefully calibrated.

The effective size of sand was 0.24 mm., having a uniformity coefficient of 2.12.

The Venturi throats were made in three slopes, — 1 to 11, 1 to 8, and 1 to 4.6, designated as Nos. 1, 2, and 3, respectively; with various internal diameters, varying by $\frac{1}{8}$ in. from $1\frac{1}{8}$ in.

to $1\frac{5}{8}$ in. For the $1\frac{3}{8}$-in. diameter, No. 4 is identical with No. 3, except that the length of the reduced sections is shortened $2\frac{3}{8}$ in., which difference slightly increases the efficiency.

The wooden box was filled with sand leveled off and then, when the jet had been adjusted to give the desired pressure, a slide in the bottom of the box permitted the sand to be dropped into the hopper.

During the early experiments, no attempt was made to break up the arching of the sand which was always more or less troublesome and which gives results below the average to about the first two hundred experiments. About three hundred experiments, including the above two hundred, were run, using the lower spray, and regulating it so that the level of water remained constant in the hopper and about 15 in. below its top before any sand was dropped; this is designated as "Method A." Tests were then made without any spray whatever after the sand was started, one hundred gallons being estimated in each case for the fall of water in the hopper; this is designated as "Method B." The five hundred runs using this method form the bulk of the data from which conclusions can be drawn, but are all subject to some little uncertainty as to the exact amount of water used. After selecting the most efficient combination of apparatus a third method was used, viz., an open spray introduced from above was tried and still better results were obtained thereby; this is designated as "Method C."

Of these, 81 tests were run in order to obtain the frictional loss with water alone flowing in 3-in. and 4-in. pipe at various velocities; also, the relative efficiency of the Venturi-shaped throat and the throat of straight bore, under maximum efficiency conditions, as determined by previous experiments; and various comparisons of nozzle pressure and face-to-face distances, in order to complete certain curves for which data were lacking. The check runs were made, following the second method described above, except that the exact quantity of water used from the hopper was determined from measurements of height at the start and finish of the flow of sand. Since the early tests had shown that the hopper screen (needed in case of stones being in the sand, only), caused decided interference in the flow of sand, by aiding the arching; no screen was used during the later runs.

For the purpose of comparison, parallel sets of experiments were made on both plain and rifled pipe of 3-in. and 4-in. diameter. The plain pipe was of lap-welded steel in 20-ft. lengths, with cast-iron flanges and butt joints. The rifled pipe was made by the National Tube Company at McKeesport and was similar in design to the rifled pipe used in the transportation of crude oil in California.* The rolls indented the pipe $\frac{3}{32}$ in. and were at a pitch of 1.5 with the axis, making one complete turn in a distance of about

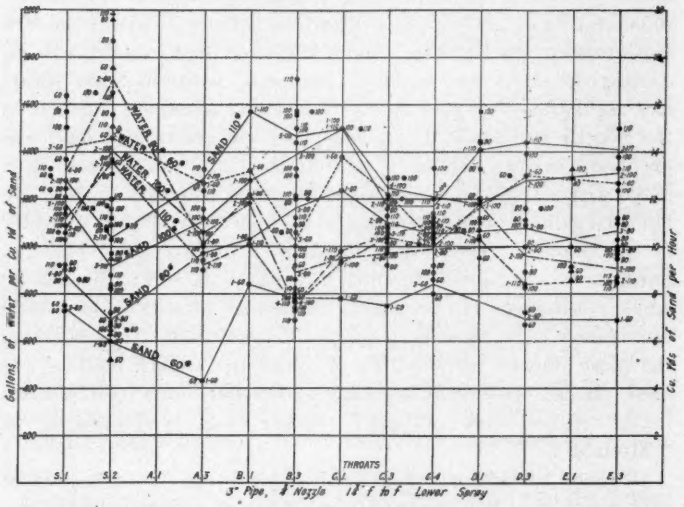
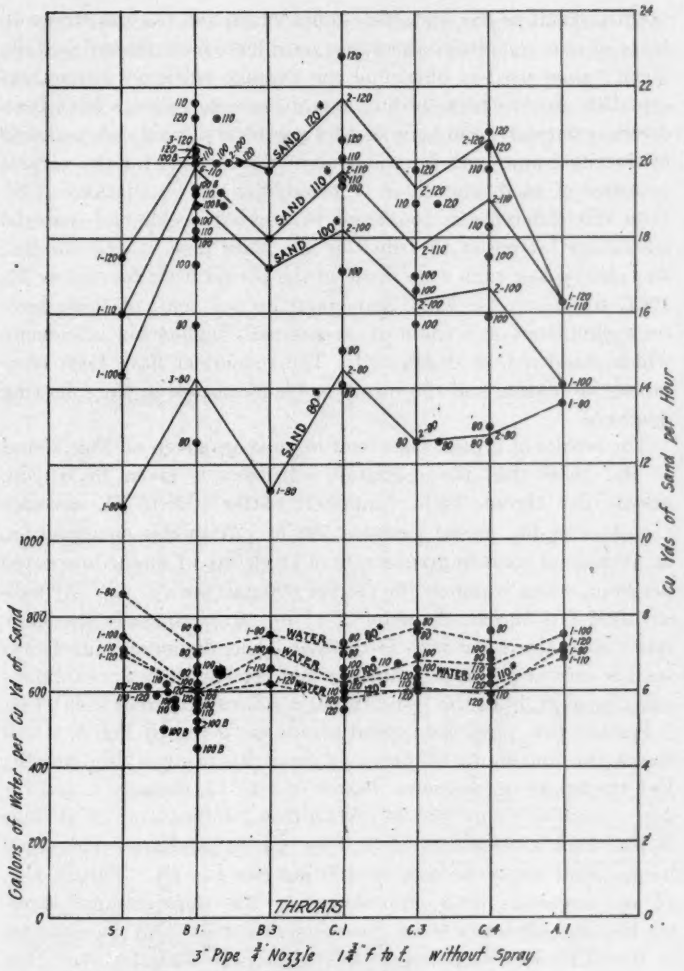

Gallons of water per Cu. Yd. of Sand
Cu. Yds. of Sand per Hour
THROATS
S.1 S.2 A.1 A.3 B.1 B.3 C.1 C.3 C.4 D.1 D.3 E.1 E.3
3" Pipe, 1" Nozzle 18" f to f Lower Spray

FIG. 3.
THROAT EFFICIENCY CURVE. (SEE NOTE ON FIG. 5.)

4 ft., and 5 ft. in the 3-in. and 4-in. pipes, respectively. It was thought that, by thus giving the mixture of sand and water a rotating movement, the sand would be better held in suspension, and trouble from stoppages, at low velocities, consequently diminished. As a matter of fact, however, the effect of the rifling was hardly noticeable, the full-bore glass cylinders, provided for observing the flow in the discharge line, indicating no perceptible whirl of the mixtures, even at velocities as high as 14 ft. per sec.

* See *Engineering News*, Vol. LV, p. 640.



THROAT EFFICIENCY CURVES
3" PIPE ¾" NOZZLE

FIG. 4.

On account of the variable results which showed sometimes in favor of one, sometimes the other, both have been plotted and the mean values used in obtaining the average efficiency curves, except that for the friction diagrams the average curves have been drawn separately, and here slightly greater frictional loss is shown in the rifled pipe both for water alone flowing and for the various mixtures of sand and water. Considering the fluctuations of results this difference is too small to warrant a claim of material advantage for either the rifled or the plain pipe. Nine hundred and ninety-four runs were made in the period from November 21, 1907, to March 14, 1908, and about 10 per cent. of these have been eliminated on account of exceptionally high or low efficiencies which could not be duplicated. The remainder have been computed, tabulated, and the results are summarized in the following diagrams.

The results of typical tests on 3-in. pipe are given on Figs. 3 and 4, and show that the maximum efficiency is given by a $\frac{3}{4}$-in. nozzle, B-1 throat, $1\frac{1}{4}$-in. diameter, batter = 1 to 11, distance f. to f. = $1\frac{3}{4}$ in., nozzle pressure 100 lb. With this combination, an average of six runs gives a rate of 19 cu. yd. of sand transported per hour, using water at the rate of 600 gal. per cu. yd. By substituting C-1 throat, diameter = $1\frac{3}{8}$ in., approximately the same result is obtained, but with D-1 throat, $1\frac{1}{2}$-in. diameter, slightly less sand is carried per hour; showing that the efficiency is not diminished by wear, until the $1\frac{1}{4}$-in. throat is somewhat larger than $1\frac{3}{8}$ in.

For the 4-in. pipe, the typical results are given on Fig. 5, which shows the maximum efficiency is given by using a $\frac{7}{8}$-in. nozzle, D-1 throat, $1\frac{1}{2}$ in. diameter, batter = 1 to 11, distance f. to f. = 2-in., nozzle pressure 100 lb. With this combination, an average of four runs gives a rate of 31.4 cu. yd. of sand transported per hour, using water at rate of 460 gal per cu. yd. Throat E-1, $1\frac{5}{8}$ in. diameter, gives approximately the same results, showing that the efficiency is not diminished by wear until the diameter of throat is somewhat larger than $1\frac{5}{8}$ in. It is readily seen that the efficiency of the 4-in. pipe is relatively greater than the 3-in. pipe.

The enlargement of the throats by wear is quite marked, the maximum being an increase in diameter of $\frac{1}{4}$ in. for the 150 cu. yd.

of sand ejected, or 0.0017 in. for each cubic yard. It is evident that an attempt should be made to secure a more economical material or form for throats.

The economical distance from face of nozzle to face of the throats is in all cases $1\frac{3}{4}$ in. for 3-in. pipe and $\frac{3}{4}$-in. nozzle, and 2 in.

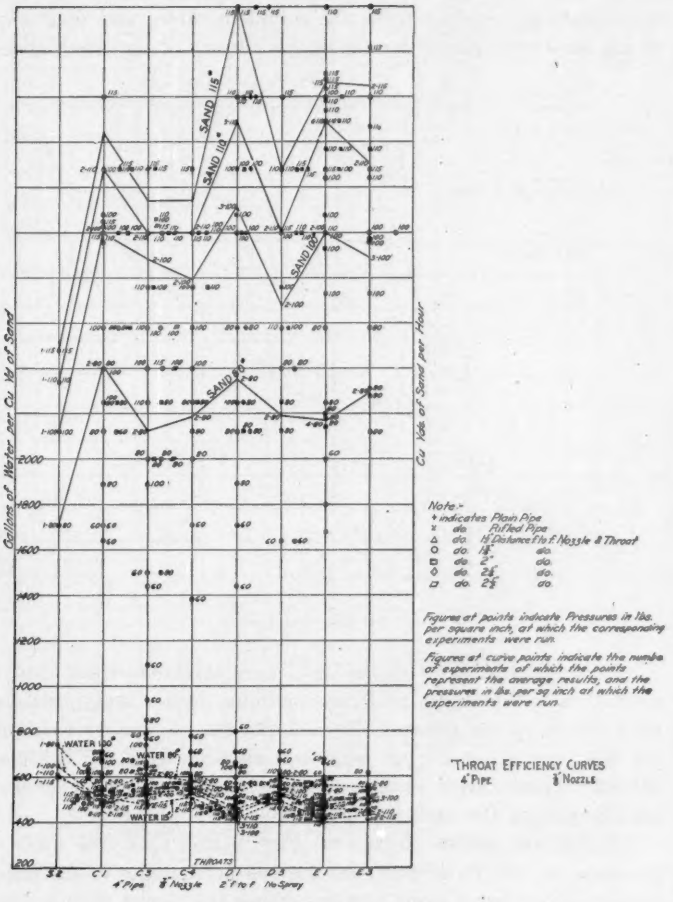

SAND 115
SAND 105
SAND 95
SAND 85
Gallons of Water per Cu. Yd. of Sand
Cu. Yds. of Sand per Hour
2000
1800
1600
1400
1200
1000
800
600
400
200
WATER 100
WATER 80
WATER 65
THROATS
A2 C1 C3 C4 D1 D3 E1 E3
4" Pipe 3/4" Nozzle 2" to f No Spray
Note:-
+ indicates Plain Pipe
x do. Rifled Pipe
△ do. ½ Distance f to f Nozzle & Throat
○ do. 1¼" do.
□ do. 2" do.
◇ do. 2¼" do.
▭ do. 2½" do.
Figures at points indicate Pressures in lbs. per square inch, at which the corresponding experiments were run.
Figures at curve points indicate the number of experiments of which the points represent the average results, and the pressures in lbs. per sq inch at which the experiments were run.
"THROAT EFFICIENCY CURVES
4" PIPE 3/4" NOZZLE

FIG. 5.

for 4-in. pipe and $\frac{7}{8}$-in. nozzle, and it is essential that the faces be centered with each other, that is, at equal distances from center line of hopper. One hundred pounds pressure at the nozzles is indicated as being the most economical; above this pressure the relative increase in efficiency is small, for the 3-in. pipe being almost a horizontal line after passing this point. Both of these statements are evident from the complete tables and diagrams, which have been placed on file in the Library of the Association.

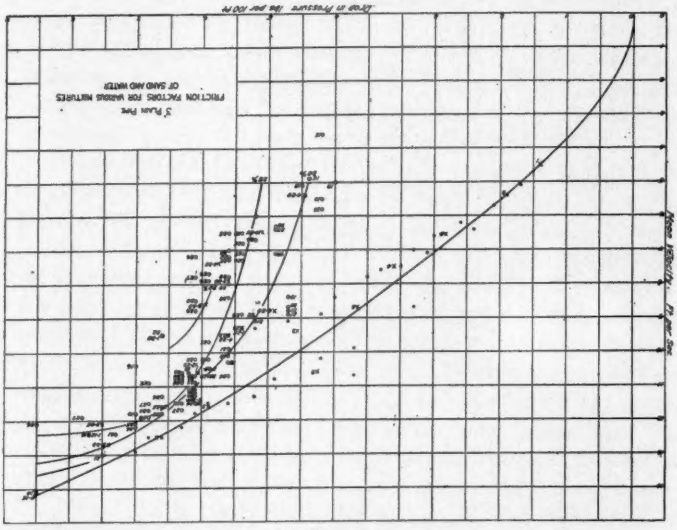


FIG. 6.

The straight throats, S-1 and S-2, were similar to those experimented with in 1905–6, and the maximum results were obtained with 100-lb. nozzle pressure, 750 gal. per cu. yd. and 14.4 cu. yd. per hour, or about 25 per cent. less efficient than the battered throat. These latter results, however, seem to exhibit greater efficiency than the earlier experiments.

The friction curves plotted on Figs. 6 to 9 show the drop in pressure per 100 ft. of pipe, for various percentages of sand and water and for water alone flowing. Since the curves were plotted

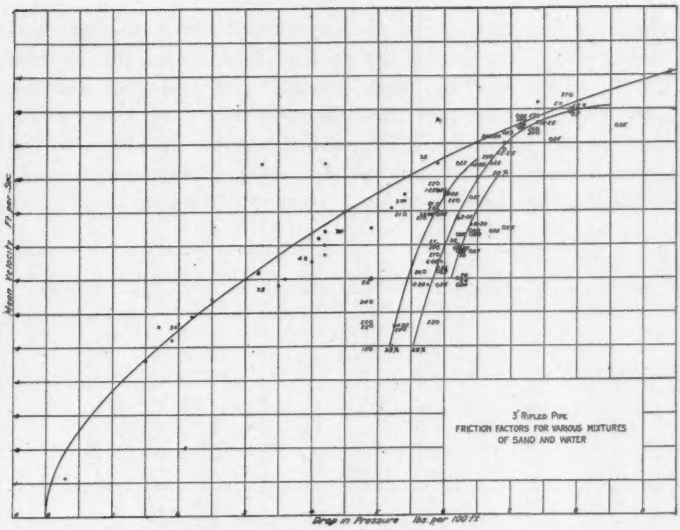

Mean Velocity Ft per Sec.
Drop in Pressure lbs per 100 Ft
3" Rifled Pipe
FRICTION FACTORS FOR VARIOUS MIXTURES
OF SAND AND WATER

FIG. 7.

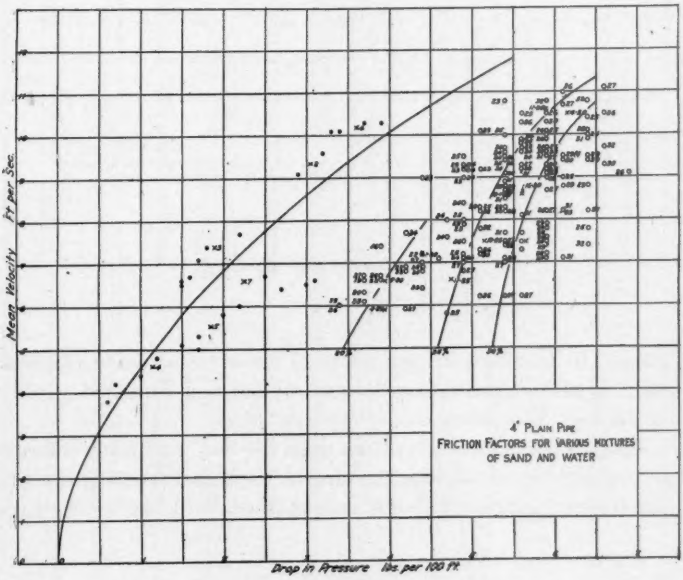

Mean Velocity Ft per Sec.
Drop in Pressure lbs per 100 Ft
4" Plain Pipe
FRICTION FACTORS FOR VARIOUS MIXTURES
OF SAND AND WATER

FIG. 8.

from the drop in the total discharge line, without considering the rise of 0.55 ft. for the first 200 ft. and the equal fall for the return 200 ft. to the sand bin, they represent the values for horizontal pipe. For the 3-in. pipe and flow at 19 ft. per sec., the loss for a half per cent. upgrade is 14 per cent. greater and for a half per cent. downgrade is 14 per cent. less. The average loss of head at the 3-in., 180-degree hose bend, about 8 ft. long, is for 3-in. pipe

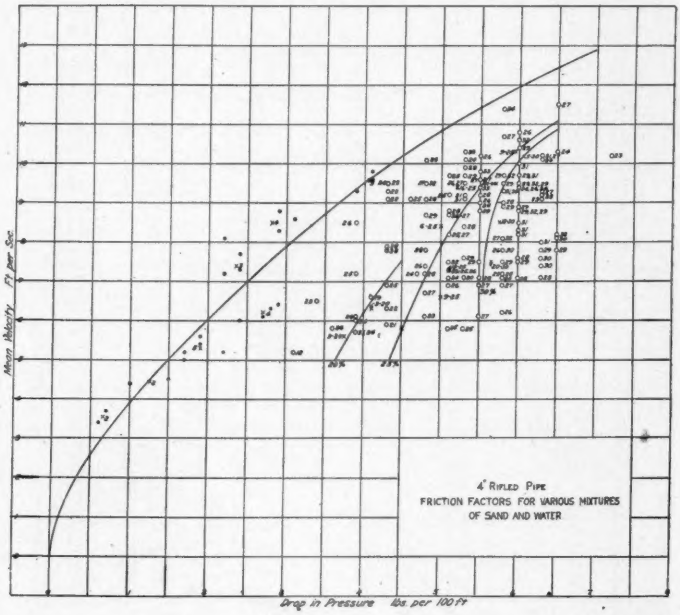

Mean Velocity Ft per Sec
Drop in Pressure lbs per 100 ft
4" Rifled Pipe
FRICTION FACTORS FOR VARIOUS MIXTURES
OF SAND AND WATER

FIG. 9.

about 1 lb. and for 4-in. pipe about $2\frac{1}{2}$ lb., which shows the marked effect of the sudden contraction of section and increased velocity in the 3-in. hose when connecting 4-in. pipe.

The temperature observations upon the sand and water indicate a very slight advantage for the sand at the higher temperature, but the lessened efficiency is not well marked until the temperature

TABLE No. 2.

Results of Sand Ejector Experiments in 1907–8.

No. of Experiments.	Dia. of Nozzle.	Dist. F. of Nozzle to F. of Throat.	Throat Designation.	Discharge Line.		Time.		Gallons of Water.	Method.	Gallons of Mixture per Minute.	Per Cent. of Sand.	Pressure.		Sand in Cu. Yd. per Hr.	Mean Veloc. Ft. per Sec.	Drop in Pres. per 100 Ft.
				Size.	Length.	Min.	Sec.					Noz.	Dis. Line.			
	In.	In.														
88		1¼	B.1	3	424	7	20	1 310	A	206	13.4	60	18	8.2	9.0	3.5
89		1¼	B.1	3	424	5	50	1 220	A	244	14.2	80	22	10.3	10.6	5.2
86		1¼	B.1	3	424	4	40	1 180	A	297	14.6	100	27	12.8	12.9	6.4
87		1¼	B.1	3	424	3	50	1 010	A	317	16.7	110	31	15.7	13.8	7.3
90		1¼	B.1	3	424	8	40	1 100	A	150	15.5	60	13	6.9	6.5	3.1
91		1¼	B.1	3	424	6	50	1 070	A	186	15.9	80	15	8.8	8.1	3.5
92		1¼	B.1	3	424	4	00	670	A	218	23.2	100	25	15.0	9.5	5.9
180		1¼	B.1	3	424	10	00	970	A	117	17.2	60	15	6.0	5.1	3.5
181		1¼	B.1	3	424	6	50	810	A	148	20.0	80	18	8.8	6.4	4.2
182		1¼	B.1	3	424	5	30	700	A	164	22.4	100	18	10.9	7 [illegible]	4.2
184		1¼	B.1	3	424	5	00	760	A	192	21.0	110	20	12.0	8.4	
220		1¼	B.1	3	424	11	20	1 080	A	113	15.8	60	18	5.3	4.9	
222		1¼	B.1	3	424	6	40	890	A	164	18.5	80	22	9.0	7.1	4.7
218		1¼	B.1	3	424	6	10	1 000	A	195	16.8	100	24	9.7	8.5	5.7
219		1¼	B.1	3	424	5	20	770	A	182	20.8	100	22	11.2	7.9	5.2
223		1¼	B.1	3	424	4	30	700	A	200	22.4	110	25	13.3	8.7	5.8
342		1¼	D.1	4	409	3	30	610	C	260	22.2	60	18	17.1	6.5	....
343		1¼	D.1	4	409	3	10	550	C	269	23.7	80	18	18.9	6.8	4.4
344		1¼	D.1	4	409	2	50	560	C	305	23.5	80	17	21.2	7.7	4.2
345		1¼	D.1	4	409	2	40	550	C	319	23.7	100	19	22.5	8.0	4.7
442		2	D.1	4	409	2	20	410	C	306	28.4	80	23	25.8	7.7	5.6
443		2	D.1	4	409	1	50	370	C	367	30.1	100	24	32.8	9.2	5.9
444		2	D.1	4	409	1	40	340	C	385	31.5	110	27	36.0	9.7	6.6
456		2¼	D.1	4	409	2	40	470	C	290	26.2	80	23	22.5	7.3	5.6
457		2¼	D.1	4	409	1	50	370	C	367	30.1	100	27	32.8	9.3	6.6
458		2¼	D.1	4	409	1	40	350	C	391	31.0	110	26	36.0	9.9	6.4
459		2¼	D.1	4	409	1	30	340	C	428	31.5	115	26	40.0	10.8	6.4
514	1	2	D.1	4	409	2	11	530	C	382	24.3	80	23	27.5	9.6	5.6
515	1	2	D.1	4	409	2	04	510	C	393	24.9	90	23	28.9	9.9	5.6
516	1	2	D.1	4	409	1	58	510	C	413	24.9	100	26	30.4	10.4	6.4
611		1¾	D.1	4	409	3	07	460	C	244	26.5	80	22	19.1	6.2	5.4
612		1¼	D.1	4	409	2	20	350	C	280	31.0	100	25	25.8	7.0	6.1
613		1¼	D.1	4	409	2	10	340	C	296	31.5	110	26	27.7	7.4	6.4
614		1¼	D.1	4	409	1	55	320	C	324	32.5	120	25	31.3	8.2	6.1
620		1¼	B.1	3	424	3	15	510	C	25	24.9	100	28	18.5	10.9	6.6
621		1¼	B.1	3	424	3	00	500	C	267	25.2	110	30	20.0	11.6	7.1
622		1¼	B.1	3	424	2	50	480	C	277	25.8	120	38	21.2	12.0	9.0
670		1¼	B.1	3	424	6	30	570	C	134	23.2	80	20	9.2	5.8	4.7
671		1¼	B.1	3	424	4	35	450	C	164	26.9	100	25	13.1	7.1	5.9
672		1¼	B.1	3	424	4	08	440	C	180	27.3	110	28	14.5	7.8	6.6
673		1¼	B.1	3	424	3	25	370	C	196	30.1	120	28	17.5	8.5	6.6
674		1¼	B.1	3	424	2	56	340	C	219	31.5	130	30	20.5	9.5	7.1
788		1¼	B.1	3	424	3	20	520	C	247	24.6	100	28	18.0	10.7	6.6
789		1¼	B.1	3	424	3	00	470	C	257	26.2	100	28	20.0	11.2	6.6
790		1¼	B.1	3	424	3	00	510	C	271	24.9	119	30	20.0	11.8	7.1
819		1¼	B.1	3	424	3	05	490	A	225	29.2	100	28	19.5	9.8	6.6
820		1¼	B.1	3	424	3	14	520	A	224	28.0	100	28	18.6	9.7	6.6
821		1¼	B.1	3	424	3	07	500	B	225	28.8	100	28	19.3	9.8	6.6
822		1¼	B.1	3	424	3	10	520	B	228	28.0	100	28	18.9	9.9	6.6
835		1¼	B.1	3	424	2	50	460	C	268	26.5	110	29	21.2	11.6	6.8
836		1¼	B.1	3	424	3	07	520	C	264	24.6	110	28	19.2	11.5	6.6
837		1¼	B.1	3	424	3	02	520	A	238	28.0	110	30	19.8	10.4	7.1
838		1¼	B.1	3	424	3	00	480	A	223	29.7	110	30	20.0	9.7	7.1
839		1¼	B.1	3	424	4	00	700	B	226	22.4	110	30	15.0	9.8	7.1
840		1¼	B.1	3	424	2	58	490	B	233	29.2	110	30	20.2	10.1	7.1
841		1¼	B.1	3	424	2	57	480	B	231	29.6	110	29	20.3	10.0	6.8
842		1¼	B.1	3	424	5	00	900	..	180	.....	60	17	....	7.8	4.0
843		1¼	B.1	3	424	5	00	870	..	174	.....	55	16	....	7.6	3.8
844		1¼	B.1	3	424	5	00	860	..	172	.....	50	15	....	7.5	3.5
845		1¼	B.1	3	424	5	00	810	..	162	.....	45	14	....	7.0	3.3
846		1¼	B.1	3	424	5	00	770	..	154	.....	40	12	....	6.7	3.0
847		1¼	B.1	3	424	5	00	710	..	142	.....	35	11	....	6.2	2.6
848		1¼	B.1	3	424	5	00	670	..	132	.....	30	9	....	5.7	2.1
849		1¼	B.1	3	424	5	00	590	..	118	.....	25	7	....	5.1	1.6
850		1¼	B.1	3	424	5	00	510	..	102	.....	20	6	....	4.5	1.4
851		1¼	B.1	3	424	5	00	960	..	192	.....	65	19	....	8.4	4.5
852		1¼	B.1	3	424	5	00	1 020	..	204	.....	70	20	....	8.9	4.7
853		1¼	B.1	3	424	5	00	1 050	..	210	.....	75	22	....	9.1	5.2
888		1¼	B.1	3	424	4	29	430	C	163	27.6	100	23	13.4	7.1	5.4
889		1¼	B.1	3	424	5	27	510	C	149	24.9	100	26	11.0	6.5	6.1
890		1¼	B.1	3	424	5	15	520	A	138	28.0	100	25	11.4	6.0	5.9
891		1¼	B.1	3	424	5	37	570	A	137	26.2	100	25	10.7	6.0	5.9
892		1¼	B.1	3	424	5	17	530	B	139	27.6	100	25	11.4	6.0	5.9
893		1¼	B.1	3	424	6	03	620	B	136	24.6	100	25	9.9	5.9	5.9
895		1¼	B.1	3	424	5	05	520	B	142	28.0	100	25	11.8	6.2	5.9

TABLE No. 2.—*Continued.*

No. of Experiments.	Dia. of Nozzle.	Dist. F. of Nozzle to F. of Throat.	Throat Designation.	Discharge Line. Size.	Discharge Line. Length.	Time. Min.	Time. Sec.	Gallons of Water.	Method.	Gallons of Mixture per Minute.	Per Cent. of Sand.	Pressure. Noz.	Pressure. Dis. Line.	Sand in Cu. Yd. per Hr.	Mean Veloc. Ft. per Sec.	Drop in Pres. per 100 Ft.
	In.	In.														
896	¾	1¼	B.1	3	424	4	42	490	C	168	25.5	110	25	12.8	7.3	5.9
897	¾	1¼	B.1	3	424	4	58	520	C	167	24.6	110	26	12.5	7.3	6.1
898	¾	1¼	B.1	3	424	4	55	520	A	147	28.0	110	25	12.2	6.4	5.9
899	¾	1¼	B.1	3	424	4	55	520	A	147	28.0	110	25	12.2	6.4	5.9
900	¾	1¼	B.1	3	424	4	50	500	B	145	28.8	110	25	12.4	6.3	5.9
901	¾	1¼	B.1	3	424	5	12	550	B	145	26.9	110	25	11.5	6.3	5.9
903	¾	1¼	B.1	3	424	3	58	410	C	179	28.4	120	26	15.1	7.8	6.1
904	¾	1¼	B.1	3	424	4	06	440	A	157	31.5	120	25	14.6	6.8	5.9
905	¾	1¼	B.1	3	424	4	13	470	A	159	30.1	120	26	14.2	6.9	6.1
906	¾	1¼	B.1	3	424	3	55	420	B	159	32.5	120	25	15.3	6.9	5.9
907	¾	1¼	B.1	3	424	4	28	480	B	153	29.6	120	26	13.4	6.7	6.1
909	¾	1¼	B.1	3	424	16	00	1 010	C	82	15.4	25	20	3.8	3.6	4.7
911	¾	1¼	B.1	3	424	4	02	510	B	177	28.4	100	25	14.9	7.7	5.9
912	¾	1¼	B.1	3	424	4	20	510	B	164	28.4	110	25	13.9	7.1	5.9
913	¾	1¼	B.1	3	424	4	10	480	B	164	29.6	120	26	14.4	7.1	6.1

EXPLANATORY NOTES TO ACCOMPANY TABLE 2.

Length of Discharge Line.

The length of discharge lines used for all computations was found by deducting from the total length of lines; first, length of ½ bend, connecting line to hopper (7 ft.); second, length of hose connecting bend and line (6 ft.). Hence, for 3-in. Plain Pipe, L = 437 ft. — (7 + 6) = 424 ft.

Description of Methods.

A. The hopper was filled with water by the lower spray up to a convenient level, usually about 15 in. below the top of the hopper. Then the valve on the supply line was opened to the required nozzle pressure and at the same time the discharge of the lower spray was so adjusted as to keep the water in the hopper at its initial level; the flow of sand into the hopper was then started. At first this causes the water to rise; subsequently, as the sand was being drawn off, it began to drop. During this flow of sand from the hopper, the spray was shut off at such a time as to have the water at its initial level at the moment the last sand leaves the hopper. In practice, the approximate time for shutting off the spray was found to be the instant all of the one cubic yard of sand had left the feeding box.

The time required to discharge this cubic yard of sand into the hopper varied to quite a considerable extent, owing to two factors; first, the ability of the two men pushing the sand from the feeding box by means of flat sticks; second, the capacity of the different combinations of nozzles and throats to carry off the sand, as supplied. Using the ¾-in. nozzle, for instance, the sand was drawn off so slowly as to form a cone in the hopper, the apex of which shut off the feed opening completely for a time.

This difficulty of closely approximating the theoretical time for shutting off the spray is the cause of some error in the quantities of water used per cubic yard of sand, affecting all experiments run according to this method to a greater or less degree. For, when the final level is above the initial one, less water is used than gaged, more than gaged being used when the water closes below the initial level.

B. Same as method *A*, except that spraying water is introduced from above.

C. The hopper is completely filled by means of the spray, and the spray then shut off. Then the supply valve is opened to the required pressure, whereupon the water in the hopper begins to drop. As soon as it reaches a level of about 9 in. below the top of the hopper, the flow of sand is started into the hopper, causing the water to rise at first. As the sand is being drawn off faster than supplied, and more so after all the sand has entered the hopper, the water level drops and closes at from 12 in. to 28 in. below top of hopper. To determine the quantity of water used per cu. yd. of sand, 100 gal. is added to the amount gaged, as an allowance for the variable amount of water drawn from hopper.

For experiments Nos. 914–994, the initial and final levels are measured, and from these the corresponding quantities of water are computed.

Gallons of Mixture per Minute.

The sum of the water per cu. yd. in gallons, plus 1 cu. yd. of sand, reduced to gallons, = (202 gal.); divided by the time per cu. yd. of sand carried and expressed in minutes.

Per Cent. of Sand.

One cubic yard of sand in gallons = (202), divided by the sum of, 1 cu. yd. of sand in gallons (202) plus the amount of water in gallons used per cu. yd. of sand.

Nozzle Pressure.

This was read by a 4-in. pressure gage, placed on 3-in. supply line between valve and hopper. Care was taken to keep the pressure steady during the flow of sand, adjustments being necessary, especially when turning on and shutting off sprays, etc.

These explanatory notes are for the complete table, of which the above figures simply refer to nozzles B.1 and D.1, the complete table being on file in the library of the Association.

TABLE 3.

Data for Different Sand Ejectors.

No.	Place and Year.	Hopper.	Nozzle.	Throat.	Spray.	Discharge Line.		Nozzle Pressure. Pounds.	Lift. Feet.	Mean Capacity. Yds. per Hour.		Per Cent. of Sand.
						Diam. Inches.	Lgth. Feet.			Av.	Max.	
1	London, 1892	2 ft. 4 in. x 2 ft. 2 in.	½ in. and ⅝ in.	...	...	3 and 2	...	43	...	3	...	4
2	Albany, 1900	24 in. x 16 in. diam.	⅛ in.	1½ in.	1 in.	2½	100	40–50	10–12	10	12	8
3	Philadelphia, 1903	26¾ in. x 21 in.	¾ in.	1⅜ in.	¾ in.	3	...	60	...	6.7	...	11
4	Philadelphia, 1903	26¾ in. x 21 in.	⅜ in.	1 in.	¾ in.	...	...	60	...	...	...	..
5	Washington, 1908	16 in. x 22 in. x 16 in.	¾ in.	1½ in.	...	3	...	100	14	8	13	6½
6	Providence, 1908	.....	¾ in.	1¼ in.	¾ in.	4 (pipe) 3 (hose)	25 50	60	6	10	12	..
7	New Haven, 1908	3 ft. 0 in. x 20 in.	¾ in.	1¾ in.	...	3	150	38	12	6	...	5½
8	New Haven, 1908	.....	½ in.	1¼ in.	...	3	150	95	...	10	...	..
9	Reading, 1908	24 in. x 18 in.	½ in.	1½ in.	...	2½	100	70	8	36	...	20

drops below the freezing point, when the decrease is caused by the lumping of the sand.

Table 2 gives the details of the experiments with the combinations giving maximum results, being for throats B.1 and D.1.*

The results given above, together with the other published data, give an idea of the probable performance of ejectors under similar conditions which are close to the ideal. Such results cannot be hoped for in practice, but careful designing and operation will certainly prove economical in most cases on account of the lessened amount of water used.

Figures compiled from representative filter plants in 1908 are given in Table 3.

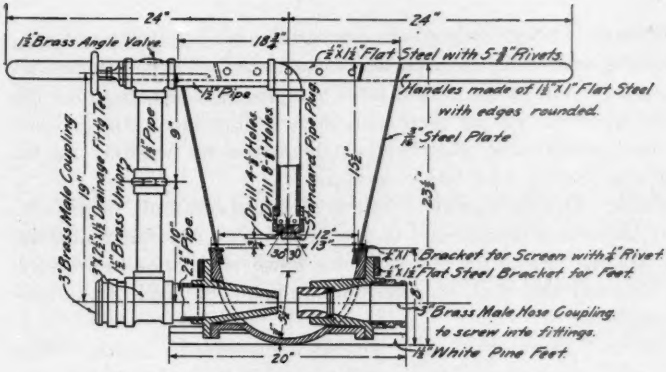
The portable ejectors and washers, designed for the Pittsburg works, are shown on Fig. 10, which also shows the design adopted for the washers for the last 10 filters constructed and shows how the results of the experiments were applied to the actual design. These washers have not been put in operation at this writing and the opportunity of comparing the actual results with experimental ones has not been given us. It will be noted that irrigators or jets, for breaking up the sand, are used in all designs; but these experiments lead us to conclude that while some form of spray is desirable to break up the arching of the sand, in the ejector this can preferably be introduced from the top. Furthermore, that the irrigator in the bottom is best for washers only, as the flow of water can thus be adjusted to displace the dirty water carrying the incoming sand and cause the dirty water to flow away over the top of the hopper.

CONCLUSIONS.

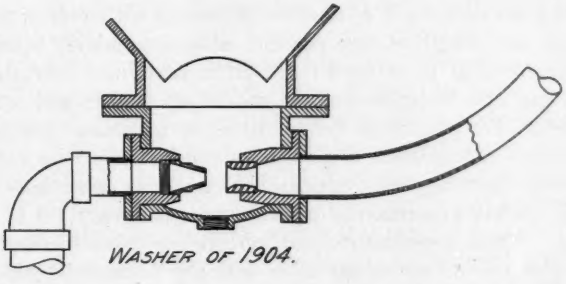
For any given installation there are a number of variables to consider, each of which has an effect, of greater or less moment, on the results. A typical design will call for, —

First. Determination of size of sand. The transporting power of the water depends upon the size of the particles, and the results given above would not apply to sand of greatly different effective size.

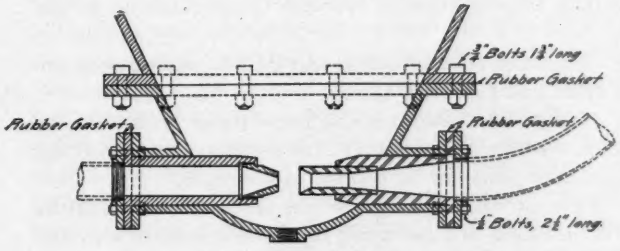
* Complete tables and diagrams of all results showing various other combinations have been placed on file in the Library of the Association, where persons interested may refer to them.



EJECTOR OF 1904.



WASHER OF 1904.



WASHER OF 1909.

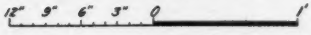


FIG. 10.

Second. Determination of quantity to be handled per hour. This is governed by the number of men which it is convenient to use per ejector, in the case of hand scraping of filters, and may be taken as 10 cu. yd. per hour with three to four men. In the case of machine scraping, much greater quantities are possible, due to uniform feeding and larger ejectors.

Third. Determination of length of transportation. This is a very important feature and is one upon which experimental data are lacking. From the above results, however, friction losses may be obtained and thus the necessary pressure at head of the discharge main.

Fourth. Determination of available pressure at nozzle. The higher pressures give better results, but 100 lb. to 110 lb. per sq. in. may be taken as the limit, except in special cases where higher pressure is readily available.

With these data it will be possible to determine the size of nozzle and pipe and length of pipe possible, after determining upon the velocity required to transport the given material. The size of throat can also be approximated and easily determined after a few tests. For conditions similar to those obtaining during the experiments the selection of sizes is a comparatively easy matter, but where there are any considerable variations from these conditions, further experimental work may be necessary.

Fifth. These experiments and our studies show further that rifled pipe has no advantage over ordinary commercial pipe.

Sixth. That reasonable hose lengths not exceeding 200 ft. are no serious determent, if of smooth bore, lined with good rubber and without serious interruptions to flow due to irregularities at the couplings.

Seventh. The most efficient nozzle and throat combinations are $\frac{3}{4}$ in. with $1\frac{1}{4}$ in. and $\frac{7}{8}$ in. with $1\frac{1}{2}$ in.

Eighth. That, with these sizes and pressures of about 100 lb., the minimum velocity was about 5 ft. per sec. and this carried the sand without any tendency to deposit in the pipes.

Ninth. That, at this velocity, the loss of head is about 50 ft. per 1,000 ft. in length of pipe, which of course increases with the velocity, as shown on the diagrams.

In conclusion, it may be well to state that the scope of the experi-

ments was limited to the particular sizes given, on account of the necessity of adapting the throats and nozzles to the then existing hoppers and pipe connections.

DISCUSSION.

CHESTER F. DRAKE, ESQ.* At Pittsburg portable ejectors are being used for the removal of the dirty sand from the filters to the washers in the galleries. Thence the sand is again ejected through the piping system to restoring machines placed in filters of low sand.

Believing that the practical features concerning durability and efficiency of the materials used will be of interest, we shall first state our experience along those lines.

The portable ejectors were made by E. M. Nichols, of Philadelphia. They consist of a cast-iron bowl surmounted by a sheet-iron petticoat.

The ejector nozzle is of hardened tool steel. The actual wearing part is $1\frac{3}{4}$ in. long, $1\frac{1}{4}$ in. outside diameter and $\frac{3}{4}$ in. bore.

The ejector throat is of chilled cast iron. It is about 7 in. long over all. The inner portion is a Venturi tube with the smallest diameter, $1\frac{3}{8}$ in. In a distance of 5 in. the diameter increases from $1\frac{3}{8}$ in. to $2\frac{1}{8}$ in. The bore of the throat is not finished, as such work is done by the sand passing through.

As stated by the author, we also found that a screen promoted arching and greatly decreased the quantity of sand handled. The laborers also found that the use of screens decreased their work, but a spray increased the output of sand very much.

The hose used for conveying the sand was 3-in. rubber hose; it was heavy and practically non-collapsible. The inner rubber tube has never yet shown signs of wear, in spite of the fact that the brass couplings and expansion rings wear rapidly.

The Pittsburg plant has a considerable amount of sand piping, of 3-in. and 4-in. wrought-iron pipe, with the outside coated by immersion in pipe dip. Dire disaster has been predicted for this pipe by several engineers of standing, but the pipes have been in use since December, 1907, having transported approximately

* Superintendent Pittsburg Filtration Works.

100 000 cu. yd. of sand to various parts of the plant, and we have yet to find one length of straight pipe which has shown appreciable wear, the only appearance of any wear being along the lower third of the inside surface. It is true that there has been some wear on the curve pipes near the sand washers in the galleries. In some instances we have substituted short lengths of hose for the curved pipes, with success, thus increasing the life of the equipment and decreasing the maintenance cost.

The sand lines carrying the sand from gallery to gallery are 4-in. wrought-iron pipe. The total length between galleries is approximately 565 ft. We have not experienced any more trouble in transporting sand through the long 4-in. line than we have experienced with the shorter 3-in. lines.

The nozzles of the sand washers are of brass. They are $3\frac{1}{4}$ in. long over all. The bore tapers from $2\frac{5}{8}$ in. diameter to $\frac{3}{4}$ in. diameter. Originally we brought the taper down to the front of the nozzle. This caused a fluting on the front face of the nozzle, producing a back lash which cut down the output of the hopper. It was therefore determined to run a $\frac{3}{4}$-in. bore for $\frac{1}{8}$ in. along the axis of the nozzle, after which the taper is carried out as in the previous nozzles. This has resulted in a considerably increased life of the nozzle as well as decreased clogging of the washers.

The water for sand washing, transporting, and restoring is obtained from two 5-million and one 3-million gallon D'Auria pumps which furnish wash water under 100-lb. pressure.

The dirty sand at Pittsburg is ejected, washed, transported to another bed, placed, and leveled, in one continuous process, without stops. Deducting all time for moving, placing, and removing hose and portable ejectors, the ejector handles 9.2 cu. yd. of sand per hour. Taking into account all time of moving, placing, and removing hose and portable ejectors, as well as the transfer of machines for restoring the sand, there are handled 6.9 cu. yd. of sand per ejector hour. During the first seven months of this year, we have ejected, washed, transported, and replaced approximately 40 000 cu. yd. of sand. In this work, we have used approximately 420 million gallons of settled water. It is estimated that this water costs $11.41 per million gallons pumped. This cost is divided as follows:

Labor	70 per cent.
Fuel	26 „
Supplies	4 „

It is evident, then, that the water for sand ejecting, washing, transporting, and restoring cost approximately $4 800.00, or 12 cents per cu. yd. of sand handled.

Concerning the amount of water used, we have found it advisable to run the water in the washers during the half hour of dinner. If we were drawing from a standpipe, we would undoubtedly not follow this custom. The starting and stopping of pumps takes some time, requiring the attendance of men at the washers. We found that the labor charge attending the stopping and starting overbalanced the cost of wash water in running straight through the day. We realize, however, the possibility of reducing the wash water about five per cent. by discontinuing this arrangement.

A series of analyses of wash water has been made to determine the bacterial content and turbidity of wash water after successive passages through washers. In the examination of the figures given below, it should be remembered that the sand is frequently passed through a washer in order to gain extra impetus in the transportation, rather than to receive a real washing. With this idea firmly in view, we offer the following:

AUGUST 16, 1910.

WASHING NO. 1.		WASHING NO. 2.		WASHING NO. 3.		WASHING NO. 4.		AT RESTORER.	
Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.
90 000	18 800	23 000	3 200	14 000	2 000	19 000	1 200	15 000	430

It is evident that the bacterial content of the settled water was approximately 15 000, and that two washings brought the bacterial content to normal.

MAY 3, 1910.

WASHING NO. 1.		WASHING NO. 2.		WASHING NO. 3.		WASHING NO. 7.	
Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.
500 000	28 700	150 000	3 200	45 000	800	19 000	100

MAY 10, 1910.

WASHING NO. 1.		WASHING NO. 2.		WASHING NO. 3.		AT RESTORER.	
Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.
720 000	31 500	230 000	4 000	65,000	1 100	25 000	800

We have made studies of the cleanliness of the washed sand restored to the beds. We find that 100 grams of sand shaken in one liter of distilled water produces a silica turbidity lying generally between 25 and 65 parts per million. Recent specifications for sand in new filters at Pittsburg allow a limiting turbidity of 200 parts per million under the same conditions.

MR. M. F. COLLINS.* What was said in both the papers regarding the washing of sand is very interesting to me. Of course when we make a comparison with the old Lawrence filter, we cannot have the same figures that are obtained at covered filters. On our open filter the sand must be transported from the beds to the roadway; it is then forced by the ejector to the washing machines, which are at an elevation of about 14 ft. After being washed, the sand is returned to the filter beds in wheelbarrows, which is a slow and costly method.

At our covered filter we have kept careful notes on the cost of operation. In scraping the sand from the bed we put the ejector in the middle of the filter and transport the sand to the storage bin. This operation costs us about 29 cents a cubic yard. There are times in the summer when we can wash and return the sand for the same price, but this cannot always be done, since we only spread the sand on the filter once a year; consequently we have to store it.

On the open filter it is pretty hard to make any comparisons at all, because the boys are continually throwing stones on to the beds, so that we have to have a screen on the ejector to remove the stones during the operation of sand washing. But in the covered filter we get very good results, and on the level ground we have washed in a single day 48 cu. yd. of sand. Mr. Knowles speaks of

* Superintendent Water Works, Lawrence, Mass.

100-lb. pressure, but in Lawrence we are confined to about 63 lb., so I think that with the diminished pressure that we have, and the difficulties encountered in the open filter, such as I speak of we show very good results. I would say that, so far as our sand is concerned, we find, as Mr. Knowles contends, that the further we transport it through the pipe, the cleaner the sand is when it comes out, for the agitation received in passing through the pipes helps it to scour it.

MR. ALLEN HAZEN * (*by letter*). In the first Pittsburg design to which Mr. Knowles has referred, there is a pipe shown underneath the ejector, which was called the "irrigator." That pipe plays a somewhat important function in washing the sand which was not mentioned by Mr. Knowles. We have used the irrigator in all sand-washer designs since this first Pittsburg design.

In the earlier washers at Hamburg, Albany, etc., the sand was freed from dirty water by a process of dilution. Every time it went through the hopper some of the dirty water was separated and some clean water was mixed with it, and so the dirty water was diluted until finally a degree of dilution was reached where there was not too much dirt left. The function of the irrigator was to introduce clear water at the bottom in a special chamber of such size that the sand would settle down into it, and the clean water would be carried forward with the sand, while substantially all of the dirty water was displaced. With this arrangement there was a better separation of dirt in a single hopper than had previously been reached with several hoppers.

Mr. F. F. Longley, now resident engineer of the Toronto Filters, formerly at Washington, has made very numerous and painstaking investigations of the relations between the size of jet, the size of throat, the pressure of water supplied to the jet and the pressure of water obtained at the discharge, and the frictional resistance of mixtures of sand and water in piping. These investigations have extended through at least six years, including some preliminary experiments that I made at Washington. Many of these experiments have been written up for office use and many designs have been based upon them. I have thought that some time Mr. Longley and I would publish a description of this work, but it

*Consulting Engineer, New York City.

has been postponed because added data is being accumulated from time to time. A very concise statement of some of the leading results is presented in the American Civil Engineers' Pocket-Book, published by Wiley & Sons, pages 932–935.

In general, the Venturi-shaped throat yields considerable more pressure than the throats of shorter length and sharper pitch that were used in all the earlier sand washer designs, and ejectors of this type should be used in all cases where the highest efficiency is desirable. More recently, throats made of straight pieces of water pipe have been used. Under favorable conditions the pressures obtained with these come within ten per cent. of those reached with the Venturi throats; and where high efficiency is not important, this type of throat is convenient.

To take up dirty sand scraped from a filter, about one volume of water is required to break down one volume of sand, making a slush mixture having sixty per cent. of solid sand by volume and a specific gravity of 1.59. This is an average result, and is taken as the basis of calculation. In handling clean sand less water may be used and slush of a higher specific gravity obtained.

With an ejector taking up slush of this kind there is a definite relation between the percentage of sand in the mixture that can be thrown and the percentage of pressure that can be developed by the ejector. Thus, with 5 per cent. of solid sand in the discharge by volume and an ejector of good design, a pressure at the discharge of 50 per cent. of the jet pressure may be reached; with 10 per cent. sand, 37 per cent. of the pressure may be reached; and with 15 per cent. sand, 28 per cent. of the pressure, etc.

Generally speaking, the smaller per cent. of sand in the discharge, the further sand can be carried or the higher it can be lifted; but, on the other hand, more water is required to make it go. Practically speaking, for any given condition an equilibrium will be reached with full feed of slush to an ejector at which the per cent. of sand in the discharge water is as high as can be maintained with the conditions of discharge and elevation that actually exist. These conditions may be calculated with sufficient accuracy for all practical purposes by a few simple formulas based upon the results of the experiments above mentioned.

In the first place, a tabular statement of the conditions obtaining in good ejectors at approximately average efficiency is given. This is for ejectors of the best shape but somewhat worn and not quite in the best condition. With everything in the best condition the results will be better, while with much-worn throats the efficiency will fall off from the figures given.

Per Cent. of Sand in Water Thrown by Volume.	5	10	15	20	25	30
Specific gravity of mixture	1.05	1.10	1.15	1.20	1.25	1.30
Per cent. slush by volume	8.3	16.7	25.0	33.3	41.7	50.0
Per cent. nozzle water by volume	91.7	83.3	75.0	66.7	58.3	50.0
Weight of slush per part water from nozzle	0.15	0.32	0.53	0.80	1.14	1.59
Q = ratio total weight of discharge to weight of jet water	1.15	1.32	1.53	1.80	2.14	2.59
P = proportion of jet pressure developed in discharge	0.50	0.37	0.28	0.20	0.14	0.10
T = ratio of diameter of throat to diameter of jet	1.18	1.33	1.50	1.73	2.02	2.38
V = ratio of velocity in throat to velocity in jet	0.79	0.68	0.59	0.50	0.42	0.35

For water alone, $V = \frac{Q}{T^2}$.

For sand mixtures, $V = \frac{Q}{T^2 \text{ Sp. Grav.}}$.

The specific gravity of 10 per cent. sand is 1.10, etc., closely enough for this calculation.

For any given ejector the amount of pressure that can be developed added to the velocity through the throat in terms of velocity in the jet is approximately constant. In other words, with a given ejector you can have so much velocity or so much pressure, or corresponding proportions of each, but as you get more of one you get less of the other. With ejectors of the Venturi type, working with water alone, this may be expressed by the equation:

For water, $(P+V)T^{1.4}=1.75$.

When mixtures of sand and water are thrown, the law is the same, but the specific gravity of the mixture is greater, and the diameter of the throat must be reduced to give otherwise corresponding results. With the maximum percentages of sand that can be thrown in each case, the equation becomes:

For sand, $(P+V)T^{1.6}=1.75$.

For general use, without refinements, the equation may be written:

In general, $(P+V)T^{1.5}=1.65$.

This is more easily solved on an ordinary slide rule and the constant is taken a little lower to allow for falling off in efficiency under various conditions.

Following the nomenclature used above, T should be so selected that QV will equal 0.9. No very great falling off in efficiency will be found with values of T such that QV is between 0.8 and 1.0. Within this approximate range the pressure that may be developed varies inversely as the square of Q. Expressed as an equation:

$$PQ^2=0.65.$$

Again, the figure given as 0.65 is not quite a constant; 0.7 and even 0.75 are obtained in special experiments under favorable conditions, and 0.65 is what should reasonably be obtained under average working conditions with a good design and parts replaced before they are too much worn.

These equations are all approximate. They are not strictly consistent among themselves, but they do represent substantially the practical conditions that have been found in ejectors under conditions of actual use, and they serve to allow these conditions to be computed in advance with sufficient accuracy for all practical purposes.

Ejector parts are best made of common cast iron. We have made them experimentally of brass, bronze, steel, and of specially hardened materials, but no increased wear was obtained from any of these justifying the added expense. The simple cast-iron parts wear substantially as long as the case-hardened ones or those of any special material.

The friction of mixtures of sand and water in pipes may be estimated by computing the friction of water alone at the same velocity in the pipe and adding 3.5 ft. per thousand for each per cent. of sand in the mixture. With 6-in. or larger pipe only 2.5 ft. per thousand need be added, while for 2.5 in. hose 4.5 ft. per thousand are to be added.

Those figures are sufficiently close for velocities 5 ft. per second

and over. Between 3 and 5 ft. per second the frictions will somewhat exceed the amounts so computed, especially near the lower limit, and below 3 ft. per second sand and water mixtures will not flow steadily.

In calculating the yardage, per cent. of sand in the mixture, etc., use —

$$\text{Velocity ft. per sec.} = \frac{137.5 \times \text{cu. yd. sand per hour}}{\text{Per cent. sand in discharge} \times \text{diameter}^2}.$$

$$\text{Cubic yards per hour} = \frac{\text{Per cent. of sand} \times \text{velocity} \times \text{diameter}^2}{137.5}.$$

The frictional resistance of various quantities of sand and water in pipes of several sizes are shown in tabular form below.

Cubic Yards per Hour.	Per Cent of Sand in Discharge.					
	5	10	15	20	25	30
			2½-Inch Pipe or Hose.			
4	480	165	130			
6		310	180	160	170	
8		500	280	200	180	200
10			390	260	220	210
			3-Inch Pipe or Hose.			
6	420	142	108	128		
8		225	136	125		
10		320	180	142	142	170
12		430	240	170	154	160
14			300	205	175	170
16			380	250	200	182
			4-Inch Pipe.			
8	180	74	70			
10	280	97	77	87		
12		126	89	88		
14		160	102	92	102	
16		200	120	102	104	117
18			140	111	108	117
20			160	123	113	120
22			184	135	120	123
24			210	152	130	128

Cubic Yards per Hour.	5	10	15	20	25	30
		5-Inch Pipe.				
10	98	50	55			
15	195	75	62	71		
20	320	110	76	75	83	
25		160	94	84	88	
30		210	115	98	94	100
		6-Inch Pipe.				
20	140	56	51	62		
30		97	67	66	75	
40		150	92	76	78	86
50		210	122	95	86	90

Mr. Knowles finds that increase of pressure above one hundred pounds does not give corresponding increase in capacity. With a given ejector this is often true, because with the higher pressure more water passes through the jet, the discharge pipe is filled with jet water alone, and there is no room left to take up sand. In the same way, if the jet is made too large, less sand will be taken up than with a smaller jet. Other things being equal, the size of jet should always be reduced when the pressure is increased. If this is done, there will always be an increase in the distance that sand can be carried or in the height that it can be lifted with an increase in the pressure of the feed water and this increase in distance and height is substantially proportional to the increase in pressure. On the other hand, the wear and tear of the apparatus increases rapidly with high pressure, and for ordinary work one hundred pounds may be a reasonable limit.

Up to the time of the design of the Washington plant, the largest piping used in connection with sand washing or handling was three inches in diameter. I became satisfied that there would be advantages in the use of 4-in. pipe and it was used. Up to that time the largest quantity of sand that had been handled was five or six cubic yards per hour. With the larger pipe at Washington the quantity of sand handled at once jumped to 10 and even to 12 cu. yd. per hour. It would obviously be possible to use 5-in. pipe and increase the yardage, but it may be doubted whether the business about an ordinary filter plant will warrant this. For special purposes, five or six inches and even larger piping may be advantageous.

With 100 lb. pressure and 4-in. piping and a 0.7 jet, 10 cu. yd. of sand per hour can be carried horizontally for about 600 ft. or lifted 40 ft.; or a proportional amount of both lift and carry may be obtained; 15 cu. yd. per hour can be carried horizontally 400 ft., or lifted 30 ft.; and 20 cu. yd. per hour can be carried horizontally 250 ft. or raised 22 ft.

Generally speaking, 50 ft. of 3-in. discharge hose from the movable ejector to the end of the 4-in. pipe has as much resistance as from 100 to 150 ft. of 4-in. pipe, so that as a practical proposition with the washer on the roof of a covered filter with 0.7 jet and 100 lb. water pressure, we have 15 ft. lift and 50 ft. 3-in. hose and about 350 ft. horizontal run in 4-in. pipe, as a practical limit, at which 10 cu. yd. per hour can be handled. With longer runs, smaller quantities, and with shorter runs larger quantities up to 15 cu. yd. per hour and more may be handled.

In making calculations, the most convenient procedure is to assume a certain number of cubic yards per hour and certain lengths of discharge piping and elevations, find out what the frictional resistance in these will be with various percentages of sand in the discharge, and then calculate what pressures of feed water will be required to produce these conditions. If the required pressure of feed water much exceeds that which is available, then the assumed conditions are too difficult and must be made easier. On the other hand, if it comes within the limit of pressure that is available, the desired results will be reached, and making the calculation for a series of percentages of sand in the discharge water, and then interpolating from the results, a very close approximate figure can be obtained for the largest per cent. of sand in the discharge water that will be carried; and conversely, for the smallest size of jet that will accomplish the desired results.

By following out these calculations systematically it will be possible to be quite certain in advance of securing the desired results and also of securing a design that will do it with as small a quantity of water as can be made to accomplish the purpose.

Mr. Francis F. Longley * (*by letter*). In connection with the operation of the slow sand filters at Washington, D. C., the writer had an opportunity, a few years ago, of studying certain

* Resident Engineer, Filtration Plant, Toronto, Ont.

problems relating to sand washing and handling. Investigations were made on the frictional resistance of sand and water in piping, and laws were determined for computing the loss of head in 3-in. and 4-in. pipe. The relations between the sizes of jet and throat of ejectors, the quantity of material that could be handled, the pressure of water at throat and jet, etc., were also studied, and the results are reviewed in the following discussion.

Friction of Sand and Water in Pipes. The equipment available for the study of the friction of mixtures of sand and water in pipes consisted of the 4-in. wrought-iron pipe of the sand washer system supported permanently along the side walls of the filters; the 3-in. flexible hose used to connect up the ejector box with the 4-in. wrought-iron pipe; the ejector box; a measuring box for sand; meters to be placed on the pipe or hose lines; the differential mercury gages, etc. The determination of the loss of head consisted simply in establishing a steady flow for various conditions and measuring accurately the pressure at two points some distance apart or the difference in pressure at these two points on the pipe line. The first experiments were carried out by the use of pressure gages located at two points on the line. These pressure gages had dials graduated to 30 lb. The least graduation of the dials was one pound and the least reading that could be depended upon, due to the lack of refinement of the gage, was probably one quarter pound. The maximum difference in pressure at the two points chosen for the gages was only about 12 lb., and the usual difference, of course, much less than that. The least reading of the gage, therefore, represented so large a percentage of the difference in pressure usually observed that the accuracy of the observation was not nearly what was desired. The need of some more refined method of measurement was therefore very soon demonstrated. A differential mercury gage was then rigged up, consisting of a long U-tube of glass attached by suitable connections to a ½-in. wrought-iron pressure pipe which was carried along the 3-in. hose or 4-in. pipe to the points on the pipe at which the difference in pressure was to be observed. Cocks for checking the oscillations which resulted from the continual variations in the conditions of flow in the pipes, especially at low velocities, and for blowing off the ½-in. pressure pipes and

clearing them of sand, were provided, and every precaution taken to make the readings consistent. The arrangement of the pressure piping, differential gage, etc., is shown in Fig. 11. The greatest care was used in the placing of the ½-in. pressure pipe and the differential mercury gage to avoid the trapping of air in high pockets of the pipe, as it was found that such accumulations of air affected the readings of the gage to a considerable degree.

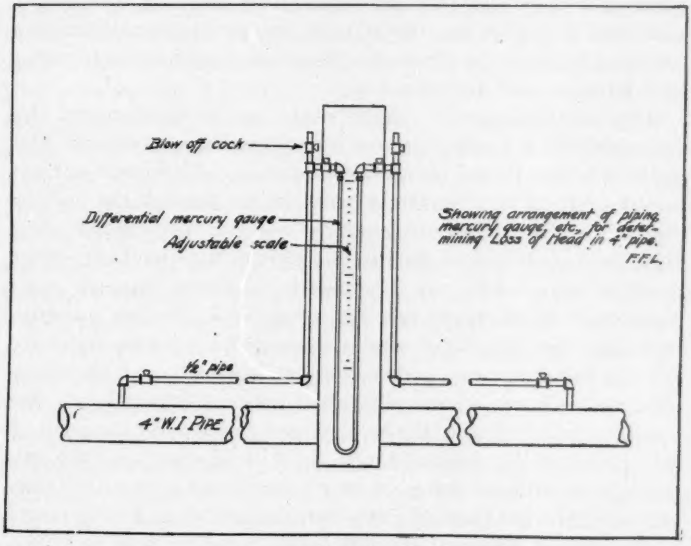

Blow off cock
Differential mercury gauge
Adjustable scale
½" pipe
4" W.I. PIPE
Showing arrangement of piping, mercury gauge, etc., for determining Loss of Head in 4" pipe.
F.F.L.

FIG. 11.

It was necessary to determine the following factors in this problem: The difference in pressure at two points a measured distance apart on the line under observation; the quantity of water passing through that section of hose or pipe, and the quantity of sand. One of the movable ejectors was hooked up in the usual way by means of two lines of 3-in. hose to the pressure pipe line along the wall. The water flowing through the section under observation could then most conveniently be measured in two parts, viz., the water supplied to the nozzle and the water sup-

plied to the irrigator. Two 3-in. meters were used for this purpose; one on the main supply to the nozzle of the ejector box and the other on another line of 3-in. hose supplying the irrigator. A separate line of hose to the irrigator is not needed, of course, in the regular operation of an ejector, but it was used here for convenience in the measurement of the water quantities. For the measurement of the sand flowing through the pipe or hose line under observation, a rectangular bottomless box holding just one cubic yard was used. This box was filled by shoveling the scraped sand into it until it was full and the top struck with a straight-edge and the box then lifted off. Piles of an even number of yards of sand were used for each run.

With all the apparatus placed ready for the experiments, the procedure for a single test run was somewhat as follows: The water was first turned on at the jet and at the irrigator and adjusted approximately to the velocity desired through the hose or pipe under observation, the supply of water to the irrigator being fixed so that the water level in the ejector box stood at a fixed depth of about 6-in. over the nozzle to insure complete submergence. When steady flow was established, the $\frac{1}{2}$-in. pressure pipe-lines were cleared of sand and air and filled with water by opening the cocks wide and discharging water through the blow-off cocks each side of the differential mercury gage. When this condition was perfected, the cock on each line nearest the point of attachment of the pressure line to the 4-in. pipe or 3-in. hose was partially closed until there was only a very small flow at the blow-off cock. The two blow-off cocks were then closed and the pressure communicated direct to the differential mercury gage and then the cocks on the pressure lines at each side of the differential mercury gage were gradually closed until the oscillations of the mercury column already referred to were reduced to a minimum.

The gage now being ready for observations, and the water flowing as already described at the jet and at the irrigator, the ejector box was filled with sand and the sand maintained at a constant level at the top of the box from an unmeasured waste pile of sand nearby. This process was continued for several minutes, if necessary, or until the flow of sand and water in the hose or pipe had reached a reasonably steady condition. The quantity of irrigator

water taken up when feeding sand to the ejector is of course much less than when the ejector is being supplied with water alone. The irrigator valve had then to be partially closed to adjust the quantity of water to give as perfect a condition of feed as possible at the ejector without causing the box to overflow. Then, at a definitely observed time, sand was supplied from one of the measured piles of sand instead of from the waste pile, and this procedure continued until an even number of yards of sand had been fed to the ejector. Finally, the time was observed when this even number of yards of sand had been exhausted and the sand in the ejector had run down once more to its initial position level with the top of the box. This fixed the time factor and the sand factor in the experiment. Readings were taken on the two water meters at the beginning and end of the run and also incidentally at intermediate times during the run in order to check up from time to time, if desirable, the uniformity of the supply. At the differential mercury gage-board readings were taken of the height of the mercury column at intervals of thirty seconds throughout the entire measurement period. The average of these was assumed as representing the difference in pressures at the two points of connection of the pressure pipe to the pipe or hose under observation

The results of these observations were then brought together, the percentage of sand in the mixtures determined, the velocity of the mixtures through the pipe or hose under observation determined, and the loss of head in feet per thousand feet computed from the observed readings of the differential mercury gage. These points were then plotted with loss of head per thousand feet as ordinates, velocity in feet per second as abscissæ, and the percentage of sand in the mixtures noted for each point so plotted. The problem then presented itself of determining from this data a suitable law of variation of the friction for different percentages of sand. A little study indicated that, for any given velocity which was great enough to keep the sand in suspension in the pipe, the increase in friction for equal increases in percentages of sand and slush was approximately constant. As an illustration of this, the points on the diagram corresponding to the $\frac{1}{2}$-in. nozzle covered a very small range of velocities. A mean line was

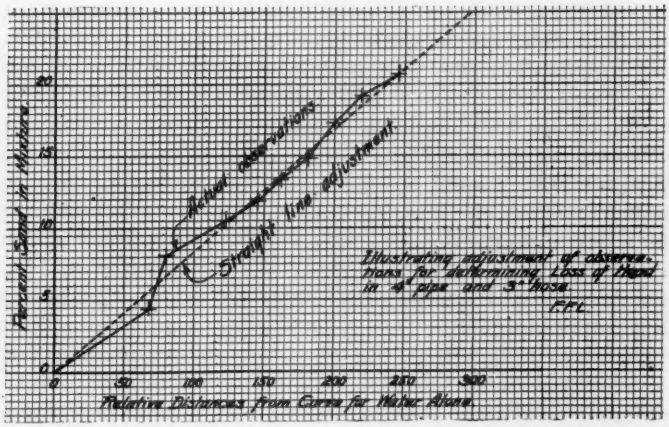

Actual observations
Straight line adjustment
Illustrating adjustment of observations for determining loss of head in 4" pipe and 3" hose.
FHL
Relative Distances from Curve for Water Alone.

FIG. 12.

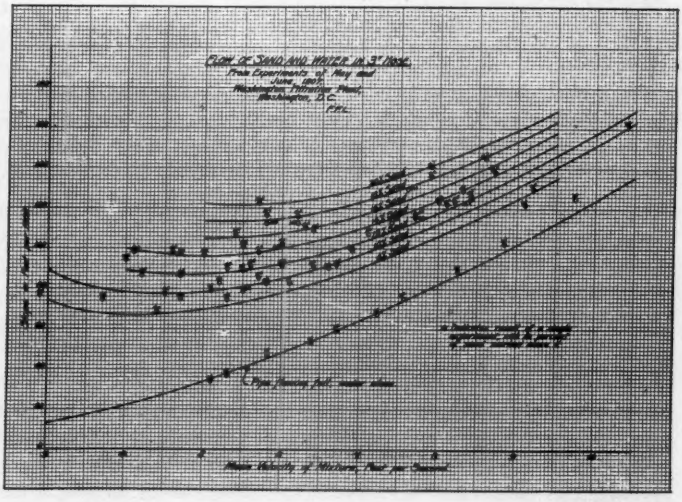

FLOW OF SAND AND WATER IN 3" HOSE.
From Experiments of May and June 1907
Hydraulic Laboratory, Pearl
Washington, D.C.
FHL

FIG. 13.

drawn through these points and the distance was measured along this line to the several points from the curve which had been carefully determined with the same equipment for the friction with water alone. It was found that these distances bore practically a constant ratio to the observed percentage of sand in the mixtures. This may be seen from Fig. 12, which is intended to illustrate this method of adjustment of observations.

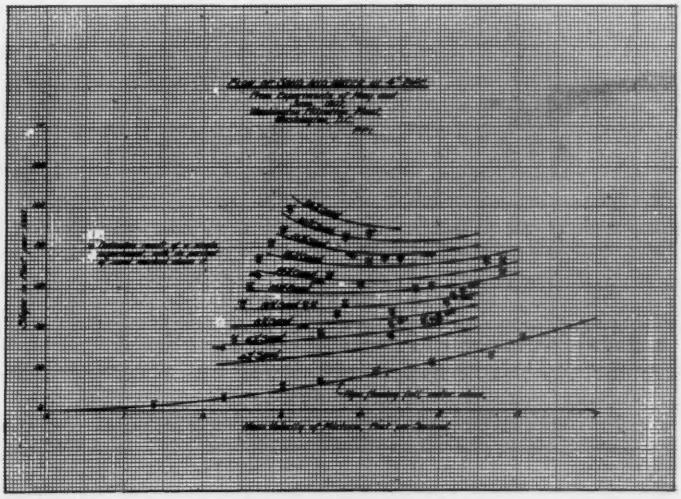


FIG. 14.

A study of other similarly related points showed that the same law applied very well, and consequently all the observations were classified according to small ranges of velocity. This method was applied for each set of figures and the points so determined used to plot curves. These curves are shown on Figs. 13 and 14, which mean substantially that the observations have been reduced to the basis of a factor to be multiplied by the percentage of the sand in the mixture and added to the friction for water alone for that velocity. These results may be stated in tabular form as follows:

FACTOR TO BE MULTIPLIED BY PER CENT. OF SAND IN THE MIXTURE AND ADDED TO THE SLOPE FOR WATER ALONE AT THE SAME VELOCITY.

	3-in. Hose.	4-in. Pipe.
Water alone, C =	134	136
Velocity, 3 ft. per sec.	7.5	4.0
" 4 ft. "	5.5	3.5
" 5 ft. " "	4.4	3.0
" 6 ft. " "	3.7	2.8
" 7 ft. " "	3.2	2.7
" 8 ft. " "	2.9	
" 9 ft. " "	2.8	
" 10 ft. " "	2.7	
" 11 ft. " "	2.7	

Action of Sand Ejectors. The experimental work described herein relating to sand ejectors had its beginning in connection with the design of the Water Filtration Plant at Washington, D. C., in the spring of 1904. By the authority of the officer then in charge of the Washington Aqueduct a number of tests were made under Mr. Hazen's direction to determine the power and capacity of different sizes and types of ejectors. Mr. Hazen had to experiment with, at that time, an ejector of the type used then in Philadelphia and some ejectors made from his own designs, the discharge end being patterned after the Venturi meter, and, on that account, being called a Venturi ejector.

Mr. Hazen's conception of the action of these ejectors involved from the first some more or less definite relations between pressures and velocities at the nozzle and the throat, the relative diameters of jet and throat and the quantities of material passing through the jet and throat. As a result of the first experiments mentioned in 1904, he was rewarded by finding reasonably definite relationships between these quantities, enough for him to perfect the design of the sand washing equipment at the Washington plant, which has proved itself most efficient and economical. The results of Mr. Hazen's early experiments were reviewed briefly in the paper on the filtration plant at Washington, D. C., by Messrs. Hazen and Hardy, in Vol. 57, Transactions of the American Society Civil Engineers.

As a result of these early experiments, one of his most important conclusions was the great advantage in efficiency of the

Venturi-shaped ejector over the other types of ejectors with which he experimented. The throat or discharge end of the Venturi ejector had a batter of 1 in 22. The throat of the older type of ejector used had a batter of 1 in 6. It seems that the discharge with the longer batter assisted in the recovery of part of the velocity head, or acted in some other manner to make the Venturi style much the more efficient of the two. There was not at that time, however, as much data as was needed to establish dependable laws for the action of these ejectors. It was this fact that led to further study of this problem that has been carried on since that time. During the years 1907–8 the writer carried out a large number of experiments on the action of the ejector, bringing together all the data possible upon the size of jet and throat, the pressure of water at the jet and on the discharge, the quantities of material thrown, etc. Mr. Hazen's earlier studies had made unnecessary any further comparison of the old ejectors with the sharp batter. A new type of throat had come into use at the Washington plant, however, which has been called the pipe throat. This throat was made of a piece of wrought-iron pipe, straight, cut to a length to be interchangeable with the Venturi throat. The Venturi throats wore out rapidly under the service they received, and the pipe throats made a cheap and convenient substitute therefor. The study was made, therefore, upon the two types of ejectors; first, the Venturi ejector; second, the pipe ejectors. These experiments covered the Venturi type of ejector fairly well, so that reasonably definite and certain conclusions have been drawn concerning them, and especially the advantage of this type of ejector over the old type with the sharp batter was confirmed. A large number of experiments were made with the pipe ejectors and certain conclusions concerning them were well established, but further data must be obtained before a final analysis of ejectors of this type can be made.

The analysis of the results described further on seems to indicate very much the same efficiency obtained from the Venturi ejector, and from the best designs of pipe ejectors. The results of the experiments on pipe ejectors, however, are more erratic than on the Venturi. The point upon which evidence is most needed is as to the effect of varying the length of a pipe throat of a given

diameter. In future experiments the length of the throat will be stated in terms of its diameter.

In the earlier Washington experiments it was assumed that results obtained with any given ejector carrying water alone represented what could be done with a slush of sand, weight for weight. There are so many complications and difficulties in the way of getting accurate results from ejector experiments with sand that it is much more satisfactory to study the problem with water alone if the assumption mentioned above can be shown to be a safe one. An analysis was made of a large amount of data collected during these experiments to bring out this relation which the weight of sand and water taken up bears to the weight of water alone taken up in the actual operation of the ejector. The analysis shows that, for practical purposes, it is quite safe to assume that the weight of the mixture of sand and water taken up by an ejector with perfect conditions of feed will be equal to the weight of water alone that would be taken up by the same ejector under the same conditions.

With this point demonstrated to our satisfaction, the study of the action of the ejectors proceeded with water alone. The same equipment was used for this study as was described above in the discussion of the determination of the loss of head in pipes, except that the differential mercury gage was done away with and the pressure at nozzle and throat observed by means of pressure gages. The information required from a single experiment consisted of the pressure at the nozzle, the pressure at the discharge, the quantities of water flowing to the nozzle and to the irrigator, the length of time consumed by the experiment and, of course, the exact description of the nozzle and the throat.

It was discovered early in the experiments that reliable results in the quantity of water taken up by the ejector could be obtained only with the jet continually and completely submerged. With the apparatus in shape for an experiment, therefore, the procedure was about as follows: The water was turned on at the jet until it reached the pressure desired for that particular run. The gate on the irrigator supply was then opened up wide until the jet was submerged and the water risen to a definite mark in the ejector box. It was then partially closed until the water level in the

ejector box stood just about at this mark without any but a trifling adjustment of the irrigator valve. The apparatus was then ready for the observations for a single experiment. At a definite time the two water meters were read. Readings were then taken on the two pressure gages at intervals of about fifteen seconds. At the end of a definite time the meters were read again and the experiment was ended. The valve on the nozzle supply was then adjusted to a different pressure, the valve on the irrigator supply altered to produce the same condition of equilibrium in the ejector box as before and another run was made for that pressure, and so on. The following table gives an example of the observations taken in a single run.

RUN NO. A–89.

Nozzle diameter equals $\frac{5}{8}$ in.
Throat diameter equals $1\frac{1}{4}$ in. pipe throat.

Time.	Meter Readings, Jet.	Cu. Ft. Water, Irrigator.	Pressure, Lb., Jet.	Irrigator.
1.21½	252960.0	192572.5	27	6.0
			27	6.0
			28	6.0
			27	6.0
			27	6.0
			27	6.0
			27	6.0
			27	6.0
1.30	253036.5	192633.0	27	6.0
	76.5	60.5	27.1	6.0

Time elapsed	8.5 minutes.
Water passing jet	76.5 cu. ft.
Water passing throat, 76.5 plus 60.5 equals	137.0 cu. ft.
Average pressure, jet	27.1 lb. sq. in.
Average pressure, discharge	6.0 lb. sq. in.
Mean velocity in jet	70.0 ft. per sec.
Mean velocity in throat	31.5 ft. per sec.

With this data in hand the problem became one of determining the relations between pressures, quantities, jet ratios, etc., that would apply reasonably well to any case. In Mr. Hazen's earlier experiments at Washington he made a successful analysis of his

results as has already been mentioned, with his observations reduced to the following terms:

Q equals the ratio of total weight of discharge to weight of jet water.
P equals the percentage of jet pressure developed in ejector discharge.
T equals the ratio of diameter of throat to diameter of jet.
V equals ratio of throat velocity to velocity in the jet.

For the experiment given in detail above, these quantities are as follows:

Q equals 1.79
P equals .22
T equals 2.00
V equals .45

The quantities P and Q were next plotted on logarithmic paper. For each combination of jet and throat that was experimented upon a number of runs were made at different pressures on the jet, these pressures varying from the least pressure which would take up any water at all to the maximum pressure that was available. For each run a point was plotted on logarithmic paper with the quantity P as ordinate and Q as abscissa. For each set of runs upon one combination of jet and throat there were then several of these points corresponding to the different pressure conditions just mentioned. These several points were joined by lines and each broken line thus formed showed the relations between pressure and quantity for this particular ejector throughout the entire available range of pressures. When these lines had been plotted for all the different ejectors that were tried, it was found that a straight line could be drawn coinciding with the points of maximum efficiency of a great many of these curves, viz., those which represented the most efficient combinations of jet and throat. The broken lines representing the less efficient ejectors lay entirely within, but did not touch, this enveloping line. This line has been termed the curve of maximum efficiency for the ejectors. This analysis was made separately for the Venturi ejectors and for the pipe ejectors, and is shown for the former on Fig. 15. For the Venturi ejectors the equation of this curve of maximum efficiency was found to be $C = PQ^2$, and for the pipe ejectors $C = PQ^{1.7}$. For the Venturi ejector the

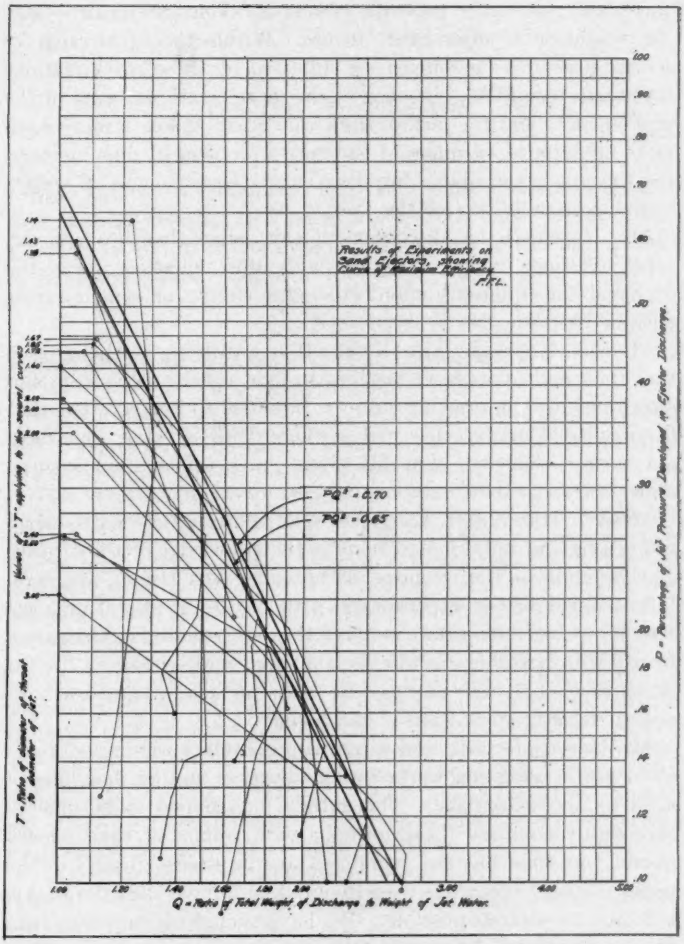

Results of Experiments on Sand Ejectors, showing Curves of Resultant Equations
F.F.L.
$PQ^2 = 0.70$
$PQ^2 = 0.65$
T = Ratio of diameter of throat to diameter of Jet.
Values of "T" applying to the several curves.
P = Percentage of full Pressure Developed at Ejector Discharge.
Q = Ratio of Total Weight of Discharge to Weight of Jet Water.

FIG. 15.

best average value of C was approximately .70, but .65 would be a more conservative figure to use for purposes of design. For the pipe ejector the best average value of C in its proper equation

was about .60, but — as in the case of the Venturi ejector — say, .55, would be a better figure to use. Within the usual range of service pressures the efficiencies indicated by these two equations differ but very little. In view of the more erratic showing of the pipe ejectors and the lack of data which will enable a more complete analysis to be made of the entire problem of pipe ejectors, the formula given above for the Venturi ejectors, viz., $C = PQ^2$, is the preferable one of the two.

Mr. Hazen, in his discussion of this paper, has brought out other relations which, together with this equation, form the fundamental equations upon which the design of sand ejectors may be based.

MESSRS. KNOWLES AND RICE. It is gratifying to the authors that their endeavors have brought to light other experiments and data upon this interesting subject, but it is to be regretted that the results of many other places where work is being done have not been chronicled, that all might have information secured under varying conditions.

Messrs. Hazen and Langley's contributions are particularly interesting and notable additions to the knowledge of the subject. The function of the irrigator, as noted by Mr. Hazen, was carefully studied in our experiments, with results as stated on page 104; where we diferentiate between the different kinds of irrigators to use with portable ejectors as compared with washers. In the latter case, only, does there seem to be an advantage with horizontal irrigator in bottom of the hopper.

Mr. Hazen's formula and accompanying tables will undoubtedly be of aid in designing works for this purpose and the handling of sand by water carriage. The authors had hoped to be able to thoroughly compare these formulæ with results of their experiments, but time has not permitted, in the desire to publish the paper, which so long has been deferred, and have the information available as soon as possible. We have thought it better to take this up at a later date.

TOPICAL DISCUSSION.

[*January 11, 1911.*]

MR. JULIUS C. GILBERT.* Mr. President, I received a letter this morning relating to a small matter, but one, I think, which interests us all. It is from the superintendent of the water works of Kingston, Mass., and is as follows:

KINGSTON, MASS., January 9, 1911.

SUPERINTENDENT WHITMAN WATER DEPARTMENT,
WHITMAN, MASS.

Dear Sir, — Thinking you may have had a case similar to the one I am writing you about, I am seeking information on what they do in other places in cases of this kind.

Two years ago a certain party applied for town water and asked to have it metered. This I thought a fair idea, as they would use more than an ordinary family, so I had a 1½-in. connection made to the main and have been supplying them from this. It is our custom to run a service pipe of sufficient size to the curbstone line of sidewalk and to put on a curbcock, the applicant connecting on same and running his own pipe to house. In this case we put in a frost-proof meter on the town side of curbcock instead of putting it in the house cellar, as the water taken had to run in a 1½-in. galvined iron pipe 350 ft. long through a salt marsh and through a river about 25 ft. wide. Some time within the last three months this pipe burst in the marsh and of course the meter ran up enormously, registering some over two hundred and fifty dollars worth of water. What I would like to know is this: Should the user pay for this wasted water or should the water department stand for the cost of pumping it?

Yours very truly,

(Signed) FRANK A. SAMPSON, *Superintendent.*

I suppose we have all had similar cases, and the question which this gentleman would like to have answered is what water-works officials in general do in regard to such things. I know you have all had experience of this kind, and I would like to hear from some

* Water Registrar and Treasurer, Whitman, Mass.

of you in regard to what you think would be a proper way to make a settlement.

THE PRESIDENT. I would like to ask Mr. Gilbert if his superintendent has answered the letter, and if so, what he advised.

MR. A. R. MCCALLUM.* I answered Mr. Sampson's letter and told him that when we had our own pumping plant we used to bear half the loss in a case like his. When there was a large loss of water by fault of the taker, we looked up the meter reading for the previous quarter, and charged him for a like amount for the quarter the loss occurred in, plus one half the excess. As we take water now from Brockton, paying meter rates, we would have to charge what the water cost us. As the Kingston Department own their plant, I thought Mr. Sampson could make the same arrangements that we formerly did, or just charge for the cost of pumping.

MR. FRANK L. FULLER.† I think the meter not having been read once in three months emphasizes the importance of reading meters at least once a month. I think once in three months is not often enough. If the meter had been read monthly, a lot of that water would have been saved.

MR. GILBERT. I will say, Mr. President, that it is common among the country water-works systems to read the meters only once in three months, and I presume that that is the custom in Kingston; unless it is a very large meter, where they use great quantities of water. In an ordinary case, if the pipe hadn't burst, they would probably have used not more than five to ten dollars worth of water in the three months.

I think that it makes all the difference in the world in a case like this where a pipe is located and under whose care it is. We all know that there are men, even in the state of Massachusetts, who will use water sometimes when we do not know it, if they can get at it in some way without our finding it out. I know that we have all had experiences of that kind. But in a good, honest case, as I think this to be, we have usually divided it, as our superintendent has said. I know we have had occasion to study and try to locate a leak for a month or two before we could find it, and in

* Superintendent Water Works, Whitman, Mass.
† Civil Engineer, Boston, Mass.

cases of that kind we have always divided up upon it. The water works would lose one half and the proprietor of the house the other.

Mr. George Cassell.* I would like to state the method used in Chelsea with regard to such cases. I have no doubt it is similar to that in most other cities, in cases of the kind that the gentleman refers to, where it is a *bona fide* case of an invisible leak, and it first comes to the attention of the consumer through the meter reading. When the man reads the meter and finds that there is an abnormal consumption, and no reason can be assigned for it, we send an inspector to ferret out the cause. If in his report he demonstrates the fact that the leak was what is known as an invisible leak, and that there was no way of the consumer or the water department knowing of it except by the meter, we take the total consumption, subtract the normal consumption from that, and split the excess between the city and the consumer.

The President. I will say, Mr. Gilbert, that I believe that if we got the opinion of every one here, it would be that the answer of your superintendent was as equitable as any which could be given to the question you have asked.

Mr. Leonard Metcalf. It might in this connection be of interest to refer to the practice of the Pennsylvania Water Company, of which Mr. Hawley is the superintendent. I remember some months ago he spoke of having a good deal of trouble from cases of this kind, not so aggravated, but where the meter dials showed a considerable excess over the normal monthly consumption. Their limited earnings prevent their reading the meters monthly. They make a practice of reading the large meters monthly, but not the small meters. As I remember it, he had something over thirteen thousand or fourteen thousand meters at the time. So he established the custom of giving to the water taker the option of having the meter read monthly instead of every three months, by the payment of a nominal charge, of, as I remember it, one dollar a year, — at all events, a nominal charge to cover the bare cost of the additional work involved to the water company. If, then, the consumer does not choose to take advantage of this option and have the meter read monthly,

* Superintendent Water Works, Chelsea, Mass.

and on the three months' reading a very large excess appears, the owner is charged with substantially the whole amount. I will not say that he does not compromise the matter in some cases, because I don't know but that he does, but I know that in many cases, perhaps in most cases, he does not compromise it, the burden being assumed to be upon the water taker.

MR. GILBERT. I want to ask the gentleman if they made the bills once a month.

MR. METCALF. Under the circumstances cited they did, — that is, if the water taker paid the charge covering the reading of the meter. It may be that no bill was rendered if the amount was normal, but at all events, it served to call attention forcibly to existing leakage.

MR. FULLER. At Wellesley, a year or two ago, we sent out a card showing a meter and the way in which it is read, explaining the reading of the meter, and asked the consumers to occasionally at least read their meters and see how the consumption was going on. I think that has done some good, and it has to a certain extent relieved the water board of some responsibility. However, we have just adopted a method whereby we have a card which is placed near the meter, and the reading for each month is recorded on that card, and we call the attention of the consumer to this. It seems to us that if in case of a leak we can show the consumer that he has a record every month of how much water he was using, it places still greater responsibility upon him.

REPORT OF THE COMMITTEE TO LOOK AFTER AND KEEP TRACK OF LEGISLATION AND OTHER MATTERS PERTAINING TO THE CONSERVATION, DEVELOPMENT, AND UTILIZATION OF THE NATURAL RESOURCES OF THE COUNTRY.

[*Presented January 11, 1911.*]

A detailed report from this committee seems uncalled for in view of the fact that probably most of the members of the Association are as well posted as the members of the committee on the chief happenings in the conservation field during the past year.

The most notable conservation event of 1910 was the Conservation Congress held at St. Paul in September. That little of technical interest occurred at this conference was the opinion of a committee of the Engineers' Society of Western Pennsylvania, which has recently submitted a report to the society named urging that that society lead in the movement to establish an Engineering Section at future conferences. If this suggestion bears fruit, it may be desirable for the committee of this Association to coöperate.

Large withdrawals of public lands containing mineral resources were made about the middle of the year by President Taft under specific congressional authority. Considerable portions of the land covered by these withdrawals had previously been withheld from settlement, but President Taft and his supporters believed that specific authorization was necessary, and such authorization was granted by Congress.

At the St. Paul Conservation Congress, already mentioned, an address was delivered by President Taft, in which he outlined his own policies regarding many important phases of conservation. On the question of water power, which perhaps more directly concerns the members of this Association than the other topics, the President presented a somewhat closely balanced judicial review of many of the points at issue. The whole address is well

worthy of careful reading and consideration, if for no other reason than because it gives an up-to-date inventory of the natural resources still owned by the United States.

A number of states have conservation commissions at work, but for the most part these commissions have done nothing as yet save to review the resources of the states which they represent and to suggest lines for future action.

As a whole, it cannot be said that the conservation movement has as yet resulted in very much definite constructive work, but it has served to call emphatic attention to the need of statesmanlike consideration of and action upon the whole subject. This has been eminently useful, since a vast amount of educational work in arousing interest and enthusiasm was necessary in order to pave the way for needed reforms.

An announcement has just been made of a new illustrated magazine to be called *American Conservation*. This publication will, apparently, be the organ of the National Conservation Association, which has its headquarters in the Colorado Building, Washington, D. C., and has as its president, Mr. Gifford Pinchot, recently Chief Forester of the United States. It is expected that the magazine will present its readers with full information regarding the progress of the conservation movement — national, state, municipal, and private.

For the committee,

M. N. BAKER,
Chairman.

REPORT OF COMMITTEE ON HYDRANT SPECIFICATIONS.

[*Presented January 11, 1911.*]

Mr. President and Gentlemen of the New England Water Works Association, — On behalf of the Committee on Hydrant Specifications I wish to present the following report.

In line with the discussion of the hydrant specifications at the annual meeting of the Association on January 12, 1910, the committee arranged for a joint conference with the hydrant manufacturers. This meeting took place on February 24, nine manufacturers being represented.

Practically all of the important items in the specifications as proposed at the last annual meeting of the Association were discussed at length, and the manufacturers were requested to submit to the committee in writing such amendments and additions as they thought should be made to the specifications. This they agreed to do.

Some time later the manufacturers held one or more meetings among themselves and prepared a complete set of specifications, following the general arrangement previously proposed by the committee, but differing from those specifications in several important features. The manufacturers sent the committee a copy of their specifications in printed form, with letter dated July 21. These specifications were submitted after having been fully considered by fourteen of the hydrant manufacturers.

It was at once seen that some of the items were open to serious question, and at least one of them was manifestly absurd, namely, a specification to permit a friction loss of twenty pounds in a two-way hydrant with two streams flowing (five hundred gallons per minute), whereas the present commercial hydrants give probably much less than five pounds under the same conditions. However, the consideration of these specifications was held for the moment, pending the results of tests of hydrants, arrangements

for which were then already being made, as mentioned later in this report.

The item which perhaps received the most attention at the February conference was the one relating to the diameter of the valve opening, and it was proposed by some if not all of the manufacturers present that, as regards friction loss and discharge capacity, a 5-in. opening was unnecessarily large for a two-way hydrant, and that a 4-in. opening was probably sufficient. This at once raised the question as to the friction loss and discharge capacity of the present hydrants having 4-in. openings, but all of the manufacturers agreed that they had made no tests and were unable to give this information.

It was promptly suggested, therefore, that sample hydrants be tested, as the next step in the work of the committee, and the committee agreed to arrange if possible for the facilities for such tests. The manufacturers on their part agreed to furnish whatever hydrants might be desired by the committee for this purpose.

It was thought that later a second series of tests might be made on hydrants with 5-in. valve openings, for comparison with the results obtained in these first series of tests of hydrants with 4-in. valve openings.

During the summer arrangements for the testing facilities were completed, thanks to Mr. F. A. McInnes, a member of your committee and also at that time acting city engineer of the city of Boston.

On August 27, a circular letter was sent to the several hydrant manufacturers, stating that the committee was ready to begin the work of testing, and asking that sample 2-way hydrants having 4-in. valve openings be sent for the proposed tests.

Several of the manufacturers at once replied stating that the hydrants would be sent promptly. One manufacturer, however, who was also represented on the special committee appointed by the manufacturers to take up this matter of hydrant specifications in conjunction with your committee, objected to sending the hydrants until certain details regarding the conduct of the tests were definitely agreed upon by the committee.

It was considered that some of these points were entirely unimportant, that others were matters which could not very easily

be determined by the committee until the hydrants were in hand, and there were still other questions asked which it was believed could best be answered only after the tests were completed. I therefore wrote this manufacturer along this line, but evidently was unable to satisfy him, and later, when the whole matter came before a meeting of the manufacturers held September 20, they refused to send the hydrants, among the manufacturers definitely taking this action being those who had previously expressed their willingness to send the desired samples.

At the same time the manufacturers requested that the committee advise them regarding the specifications which they had submitted to the committee in July.

The only courses then open to the committee for obtaining hydrants for the tests appeared to be to either buy, borrow, or steal. The Association had made no appropriation for such an unusual expenditure, the chairman of the committee did not know where to go to borrow, and we were all too law-abiding to steal. We have, therefore, had no hydrants to test and the tests have not been made.

During the past two or three months work incident to the closing of the year has prevented me from giving the matter further consideration, and I anticipate that the other members of the committee have been in much the same situation.

However, in order to advance the work of the joint consideration of these specifications by the committees of the National Fire Protection Association and the American Water Works Association, copies of the specifications as proposed at the last annual meeting of the New England Water Works Association and of the specifications prepared by the hydrant manufacturers have recently been sent to the members of those committees, and in due time it is expected that a joint conference will be held to further consider the whole matter.

While the committee were familiar with the hydrant tests made by Charles L. Newcomb at Holyoke in 1897 and 1898, on a number of the hydrants then in common use, it was believed that tests on the present makes of hydrants were desirable as showing strictly up-to-date conditions. The information which such tests would provide would be of much value to the committee in connection

with the work in hand, and we certainly expected that these tests would be made during the past year, so that we could present to the Association to-day a final report. We, however, regret that we are unable to do this, and instead can only report that considerable effort has been made to this end but without practical result.

We are particularly disappointed that the manufacturers have so signally failed to coöperate with the committee, refusing the assistance which they easily could have rendered in obtaining information which at the February conference it was considered would be of value to the committee in connection with the work in hand.

Just what help the committee may expect from the manufacturers in future, time only can tell; we do not know. Neither do we understand the present attitude of the manufacturers in this matter of hydrant specifications.

Under the conditions we are obliged to recommend that the specifications as printed in the Proceedings of the annual meeting of 1910 be still considered as the tentative specifications of the Association; and we would repeat the request of a year ago that the committee be favored with the suggestions which any member of the Association may have regarding this subject.

Respectfully submitted,

H. O. LACOUNT,
Chairman.

REPORT OF COMMITTEE ON UNIFORMITY OF HOSE AND GATE NUTS AND DIRECTION OF OPENING.

BY FRANK L. FULLER.

[*Read January 11, 1911.*]

Your committee owes an apology to the Association for not having done anything since 1906. At that time a report was made * and the committee continued. But the fact dropped out of our minds, or it did out of mine, and it was only on receiving a communication from the Secretary in regard to it that it was brought to our attention again.

That report, as you remember, was in regard to the manner in which gates and hydrants should open, and the size of gate nuts, and your committee recommended that gates and hydrants should open to the left, as that seemed to be the best way to secure uniformity, all steam valves opening in that direction, and, of course, a certain proportion of water-works valves and hydrants.

At the time of that report the question was brought up and was discussed as to independent valves which are often placed in three-way and four-way hydrants. The question was raised as to the size of the spindle and of the nut operating the $2\frac{1}{2}$-in. valve, and the committee was asked to report on the matter. Your committee now presents that report.

The Committee on Proposed Specifications for Post Hydrants a year ago † went into the matter particularly, and recommended that the stems be $\frac{3}{4}$ in. in diameter, with a stem nut $\frac{3}{4}$ in. square. This committee agrees with these suggestions.

In regard to the direction of opening, this committee is of the same opinion as expressed in our previous report, namely, that unless there are reasons as therein expressed, they should open to the left.

While the committee realizes that there are many hydrants in use with these independent hose-gate valves, they feel that, except

* JOURNAL N. E. W. W. A., Vol. XX, p. 348.
† JOURNAL N. E. W. W. A., Vol. XXIV, p. 205.

perhaps in mill yards where they are used by men who are entirely familiar with the direction of opening and the amount of leverage which should be used in opening them, and the number of turns required, for the use of the average fireman it is better to use a valve with a proper sized handwheel, screwed directly to the hose nozzle, and the hose connected with this 2½-in. gate valve.

Hydrants are made with a valve permanently connected to the hose opening, but the projection of this valve is objectionable in street hydrants, and they would be liable to injury, as pointed out by Mr. Stacy, by the small boy or the maliciously inclined.

There are no doubt points, especially in mill yards, where a three- or a four-way hydrant will do excellent service, but as a four-way hydrant with independent hose gate valves costs about double an ordinary two-way hydrant, the question may be raised whether the two two-way hydrants are not more desirable. They are simpler, and simplicity is always desirable.

This committee recommends that the fire department hose wagons carry a sufficient number of gate valves which can be screwed to the hydrants and the hose attached to these valves, the valves to be operated by a hand wheel.

A letter dated December 5, 1906, from Mr. A. W. F. Brown, water registrar, Fitchburg, treats of this subject from a practical standpoint, and the committee, therefore, adds it to their report.

Respectfully submitted,

F. L. FULLER.
FRANK C. KIMBALL.

FITCHBURG, MASS., December 5, 1906.

Mr. FRANK L. FULLER,
12 PEARL STREET, BOSTON, MASS.

Dear Sir, — In reply to yours about hydrants with independent valves, would say that we have about 128 four-way hydrants in use on pressures from 72 to 180 pounds to the square inch, and they are all right if handled properly. They are of the Chapman make and are a fine working hydrant. The independent valves are as strong as the room in the top of the hydrant will allow of making them, and will stand all the strain necessary to work the valves,

but they will not stand a man pulling on them with the leverage that the hydrant wrench will give.

The firemen sometimes leave the main valve open, having shut off the streams with the small valves, and forgetting to close the main one, and the highway department do the same. In cold weather this means a frozen hydrant soon after. The men also get excited sometimes and try to turn them the wrong way, and in that condition something has to come, and the valve is usually broken. The main valve will stand all their pulling without harm, and the small ones would if they had only the leverage that there is to a wheel valve.

The highway department sometimes leaves the small valves open and the firemen start to use it, and after attaching one line of hose and getting water, take off another cap for the second line, receiving the full 2½-in. stream, and, flying over to the other side of the road, wonder what hit them. We have never had a man hurt from being hit this way, but have had them wet several times, with narrow escapes from serious accidents. Of course they make remarks about the water department, and their lack of attention to the hydrants, but as we have not full control over their use, we cannot always know when they are used and so look them over to see their condition. We intend to look them over after being used at a fire as soon as the firemen are through.

We do not have a great amount of trouble from them, but just enough to convince me that I would rather have the hydrants without them, even if we gave the fire department a new set of valves every year or two to use on the nozzles. They carry a valve on the line of hose on each wagon to use on the two-way hydrants, and they could just as well use the others the same way.

Yours very truly,

(Signed) A. W. F. Brown,
Registrar.

Mr. George A. Stacy.* Mr. Brown's letter simply emphasizes the necessity of the water department controlling the hydrants, and also emphasizes the fact that hydrants are made for fire service and not for flushing streets, or to be monkeyed with by

* Superintendent Water Works, Marlboro, Mass.

people who don't know anything about them and who want to use them for all other purposes.

MR. MARTIN.* I think all of us who have anything to do with hydrants will echo Mr. Stacy's remarks. I move that this report be accepted as a report of progress.

MR. FULLER. I think this committee has been in existence about long enough and I hope the report will be accepted and the committee discharged, because this matter would very naturally come before the Committee to Prepare a Standard Specification for Fire Hydrants, and it seems to me unnecessary to have two committees so nearly alike.

MR. JULIUS C. GILBERT.† I think this committee is doing well so far. I notice particularly that they recommend that the valve gates open to the left, and after my experience I should say that was right. It seems to me that we are going to have pretty hard work to get specifications for hydrants which will please every one. I can hardly wonder myself that the manufacturers of hydrants do not take to this so kindly as some of the water-works people, for the reason that, as you know, it is pretty hard work to bring all our water-works people to the same mind in regard to a hydrant. I think that as long as hydrants are made there will be different kinds or different makes of hydrants which will differ in some respects. This committee may get up a pattern of a hydrant which we might feel perfectly satisfied with, and in three months from now some one will get up a hydrant that is still better. So it looks to me as though it would be a pretty difficult matter to get a hydrant that will suit everybody.

MR. J. C. HAMMOND, JR.‡ When we built our water works the question of right or left for gates and hydrants came up, and we settled it on the principle that the normal condition of a hydrant is closed, and, therefore, the nut is turned to the left, while the normal condition of a gate on the main line is open, and, therefore, we turn to the right, and there is no confusion.

The motion to accept the report as a report of progress was adopted.

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* Superintendent Water Works, Springfield, Mass.
† Water Registrar and Treasurer, Water Works, Whitman, Mass.
‡ Secretary and Treasurer, Rockville Water Company, Rockville, Conn.

PROCEEDINGS.

Annual Meeting.

Hotel Brunswick,
Boston, January 11, 1911.

President King in the chair.

The following members and guests were present:

Honorary Member.

F. P. Stearns.

Members.

S. A. Agnew, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, W. L. Beals, F. D. Berry, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, E. C. Brooks, G. A. P. Bucknam, G. A. Carpenter, George Cassell, J. C. Chase, M. F. Collins, E. R. Dyer, E. D. Eldridge, G. H. Finneran, F. F. Forbes, F. J. Gifford, J. C. Gilbert, Albert S. Glover, J. A. Gould, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. C. Hammond, Jr., Allen Hazen, H. G. Holden, W. S. Johnson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. Kimball, G. A. King, A. R. McCallum, N. A. McMillen, D. E. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, G. F. Merrill, Leonard Metcalf, William Naylor, A. S. Negus, F. L. Northrop, E. M. Peck, T. A. Peirce, W. H. Richards, Henry Roberts, C. W. Sherman, J. Waldo Smith, G. H. Snell, G. A. Stacy, W. F. Sullivan, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, L. D. Thorpe, J. L. Tighe, J. A. Tilden, D. N. Tower, C. H. Tuttle, W. H. Vaughn, C. K. Walker, J. H. Walsh, R. S. Weston, H. L. Whitney, F. B. Wilkins, G. E. Winslow. — 74.

Associates.

Anderson Coupling Company, by C. E. Pratt and C. E. Childs; Ashton Valve Company, by C. W. Houghton and Columbus Dill; Harold L. Bond Company, by F. M. Bates; Builders Iron Foundry, by G. H. Lewis and A. B. Coulters; Chapman Valve Manufacturing Company, by A. W. Hobbs; Darling Pump and Manufacturing Company, Ltd., by H. H. Davis and J. L. Hough; The Fairbanks Company, by W. D. Cashin; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; International Steam Pump Company, by E. F. Nye; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould and A. R. Taylor; Chas. Millar & Son Company, by C. F. Glavin;

H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by H. L. Weston and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall and Edw. P. King; United States Cast Iron Pipe and Foundry Co., by D. B. Stokes; Waldo Bros., by H. E. Browne; Water Works Equipment Company, by H. M. Heim; R. D. Wood & Co., by C. R. Wood and Wm. Woodburn. — 35.

GUESTS.

F. L. Weaver, G. W. Bowers, and E. H. Foye, Lowell, Mass.; William Harvey, superintendent water works, and Joseph Woods, water commissioner, Pawtucket, R. I.; Alvin C. Howes, Middleboro, Mass.; J. Kelley, Braintree, Mass.; F. Woodbury, 2d, water commissioner, Beverly, Mass., and Raymond C. Allen, Manchester, Mass.; H. P. Plimpton, water commissioner, Walpole, Mass. — 10.

The Secretary read applications for membership from Henry E. Warren, Ashland, Mass., chairman of the water commissioners, Ashland, Mass.; and A. Lincoln Fellows, Denver, Colo., engaged in irrigation and water supply work, and a member of the Utilities Commission, Denver.

On motion of Mr. Fuller, the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared elected to membership.

Raymond C. Allen, C.E., Manchester, Mass., presented a paper on "The Gas Producer Pumping Plants at Manchester, Massachusetts." The paper was discussed by Mr. Harry L. Thomas, Mr. Frank L. Fuller, and Mr. John C. Chase.

Mr. Allen Hazen read the report of Mr. M. N. Baker, chairman of the committee to "look after and keep track of legislation and other matters pertaining to the conservation and development and utilization of the natural resources of the country."

On motion of Mr. Pierce, the report was accepted and ordered placed on file, and the committee continued.

Mr. H. O. Lacount, chairman, read the report of the committee "to prepare a standard specification for fire hydrants."

On motion of Mr. Fuller, the report was received as a report of progress, and the committee continued.

Mr. Frank L. Fuller, chairman, presented the report of the committee "on uniformity of hose and gate nuts, and direction of opening."

The report was discussed by Mr. George A. Stacy, Mr. Julius C. Gilbert, and Mr. J. C. Hammond, Jr., and was accepted as a report of progress.

The report of the committee "to compile information relating to awards that have been made in water-works valuation cases," H. W. Dean, chairman, was called for. Secretary Kent, in the absence of Mr. Dean, reported that Mr. Dean has endeavored faithfully to gather material for the report, but has not been successful. He has sent out two different circulars, without being able to secure sufficient information in response to warrant making a report, as people who had the information did not like to part with it.

The following reports of officers of the Association were received.

REPORT OF TREASURER.

LEWIS M. BANCROFT, TREASURER,
In account with the New England Water Works Association.

RECEIPTS.				EXPENDITURES.	
1910.					
Jan. 1	Balance on hand		$3 449.57	Paid bills, as per itemized statement	$7 237.60
Aug. 1	Dividend People's Saving Bank, Worcester		69.94	BALANCE ON HAND.	
Nov. 1	Coupons, L. S. & Mich. So. R. R. bonds,		80.00	Deposit People's Savings Bank, Worcester	1 801.80
Dec. 1	Dividend, Mechanics Savings Bank, Reading		36.54	,, Mechanics Savings Bank, Reading	900.00
	Interest on deposits		1.14	,, Liberty Trust Co., Boston	16.39
	Rec'd of Willard Kent, Sec'y,	$5 369.46		,, First National Bank, Reading	.86
	Rec'd of Willard Kent, Sec'y, lunches	750.00			
	Rec'd of Willard Kent, Sec'y, June excursion	200.00	6 319.46		
			$9 956.65		$9 956.65

ASSETS AND LIABILITIES.

ASSETS.		LIABILITIES.	
Cash in banks	$2 719.05	Accounts payable:	
Bonds Nos. 2642 and 2644, Lake Shore & Mich. So. R. R. 4%, due May 1, 1931. Book value, $1 815.00. Market value	1 870.00	Assistant Secretary, expense	$14.94
		Editor's salary	75.00
		Expense	12.55
		Printing December JOURNAL	748.95
		Samuel Usher	83.25
		Net assets in hands of Treasurer	3 654.36
	$4 589.05		$4 589.05

Examined and found correct,
JOHN C. CHASE,
GEORGE H. FINNERAN, } *Auditing Committee.*

JANUARY 11, 1911.

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1910.

January 17	W. N. Hughes, dues book and cards	$10.00
	Samuel Usher, advance copies Hydrant Specifications	3.50
	Bacon & Burpee, reporting November and December meetings	52.50
	D. Gillies' Sons, printing ballots and envelopes	18.50
	The Brunswick, music at January meeting	15.00
24	Miss J. M. Ham, salary for January	50.00
	Chas. W. Sherman, salary as advertising agent to January 1	56.00
February 4	Richard K. Hale, salary as editor to December 31, 1909	75.00
	Richard K. Hale, expenses	7.00
	Samuel Usher, December, 1909, JOURNAL and reprints	886.97
	Boston Society of Civil Engineers, rent to December 1, 1909	100.00
	L. M. Bancroft & Son, treasurer's bond	17.50
	W. N. Hughes, stamped envelopes and printing	65.00
12	W. N. Hughes, printing	33.00
18	The Brunswick, lunch, cigars, and music, February 4	164.50
	W. N. Hughes, binding and blocking	3.55
March 5	Suffolk Engraving and Electrotyping Company, plates	2.80
	Miss J. M. Ham, salary for February	50.00
	Boston Society of Civil Engineers, rent to February 28	100.00
	Leonard Metcalf, library research, 1909	21.65
15	D. Gillies' Sons, envelopes and printing	86.72
	W. N. Hughes, printing	46.50
	The Brunswick, lunches, music, and cigars, March 9, 1910	171.50
	Thomas P. Taylor, stereopticon	10.00
19	Suffolk Engraving and Electrotyping Company, plates	7.05
22	J. C. Halden, drawing	2.50
23	Richard K. Hale, salary as editor to March 31	75.00
	Richard K. Hale, postage and expenses	8.45
	R. J. Thomas, salary as advertising agent to April 1	55.50
	Miss J. M. Ham, salary for March	50.00
	Amount carried forward	$2 245 69

	Amount brought forward	$2 245.69
March 23	Samuel Usher, printing cards and circulars	7.25
April 4	Samuel Usher, printing March JOURNAL and reprints	1 006.85
	Suffolk Engraving and Electrotyping Company, plates	2.68
13	Allyn House, Hartford, dinners, cigars, and music	193.58
16	W. N. Hughes, printing	62.00
	Willard Kent, salary to March 31	50.00
	Willard Kent, expenses	39.98
22	L. S. Cowles, expense committee on engineering building	15.00
	Bacon & Burpee, reporting January, February, March, and April meetings	131.30
30	Miss J. M. Ham, salary for April	50.00
May 12	W. N. Hughes, printing	18.50
	D. Gillies' Sons, printing	35.25
14	Chas. Dunkelberger, printing	4.00
	Wm. F. Woodburn, stationery	5.60
28	Suffolk Engraving and Electrotyping Company, plates	1.28
28	Boston Society of Civil Engineers, rent to May 31,	100.00
	Miss J. M. Ham, salary for May	50.00
	Miss J. M. Ham, expenses	69.90
June 13	Richard K. Hale, salary to June 30	75.00
	Richard K. Hale, express and postage	8.70
16	D. Gillies' Sons, printing	6.00
	Samuel Usher, printing list of members and constitution	175.50
22	R. J. Thomas, salary to June 30	63.00
	Providence, Fall River and Newport Steamboat Company	75.00
	S. S. Atwell Co., dinners	74.25
	Geo. A. King, expense conference on Uniform Accounting	39.40
	Irving S. Wood, expenses for June outing	40.65
July 5	D. Gillies' Sons, printing	26.75
7	Suffolk Engraving and Electrotyping Company, plates	9.41
	Samuel Usher, June JOURNAL and reprints	309.20
12	Miss J. M. Ham, salary for June	50.00
18	Pulsifer Paper Company, printing	3.50
	Willard Kent, salary to July 1	50.00
	Amount carried forward	$5 095.22

		Amount brought forward	$5 095.22
July	18	Willard Kent, expenses	5.00
	30	Suffolk Engraving and Electrotyping Company, plates	11.55
August	5	Miss J. M. Ham, salary for July	50.00
	18	Suffolk Engraving and Electrotyping Company, plates	6.72
	31	D. Gillies' Sons, printing circulars	10.25
		W. N. Hughes, envelopes	3.75
		Miss J. M. Ham, salary for August	50.00
September	28	Richard K. Hale, salary to September 30	75.00
		Richard K. Hale, copyright September JOURNAL,	1.00
October	5	R. J. Thomas, salary advertising agent to September 30	63.00
		W. N. Hughes, envelopes and printing	49.50
		Miss J. M. Ham, salary for September	50.00
		W. F. Woodburn, fittings for exhibit	34.41
		Willard Kent, salary to October 1	50.00
		Willard Kent, expense	31.80
		Samuel Usher, reprints	32.74
		Bacon & Mudge, report of annual convention,	110.00
	26	American Society of Civil Engineers, binding,	4.00
		Boston Badge Company, badges	51.80
		W. N. Hughes, envelopes	45.00
		Wm. E. Whittaker, tracing and lettering	2.50
November	2	The Evening Post Job Printing Office, electroplate	1.80
		Suffolk Engraving and Electrotyping Company, plates	7.40
		Samuel Usher, September JOURNAL	277.65
	10	Miss J. M. Ham, salary for October	50.00
		Miss J. M. Ham, expenses	85.01
		W. N. Hughes, printing circulars	5.00
		Suffolk Engraving and Electrotyping Company, plates	14.85
	23	D. Gillies' Sons, printing	29.50
		The Brunswick, lunches, November 9	184.50
December	9	Miss J. M. Ham, salary for November	50.00
		Suffolk Engraving and Electrotyping Company, plates	8.82
	19	Lewis M. Bancroft, salary as treasurer	50.00
		Boston Society of Civil Engineers, rent to December 31	233.33
		Amount carried forward	$6 831.10

	Amount brought forward	$6 831.10
December 31	Bacon & Mudge, reporting November and December meetings	49.50
	Miss J. M. Ham, salary for December	50.00
	The Brunswick, lunch, music, and cigars, December meeting	195.00
	H. K. Higgins, stereopticon	12.00
	W. N. Hughes, printing circulars	1.50
	Willard Kent, salary to December 31	50.00
	Willard Kent, expenses	10.00
	D. Gillies' Sons, circulars and ballots	38.50
		$7 237.60

SUMMARY OF BILLS PAID.

1909 Bills Paid.

Office:			
Rent	$133.33		
Printing	28.50		
		$161.83	
JOURNAL:			
Reporting	$52.50		
Printing	886.97		
Editor's salary and expenses	82.00		
Advertising agent	56.00		
		1 077.47	
Committees:			
Printing	$3,50		
Library search	21.65		
		25.15	
			$1 264.45

1910 Bills Paid.

JOURNAL:		
Advertising agent	$181.50	
Plates	74.36	
Printing	1 626.44	
Reporting	290.80	
Editor's salary	225.00	
Editor's expenses	23.15	
Envelopes and circulars	52.25	
		$2 473.50

Office:			
Secretary, salary	$200.00		
Secretary, expense	86.78		
Assistant Secretary, salary	600.00		
Assistant Secretary, expense	154.91		
Rent	400.00		
List of members	175.50		
Library	7.55		
Printing, stationery, postage	200.25		
		$1 824.99	
Meetings and Committees:			
Stereopticon	$22.00		
Lunches, cigars, and music	924.08		
Badges	51.80		
June excursion	216.65		
Committee on Engineering Building	15.00		
Committee on Uniform Accounts	39.40		
Committee on Exhibit	34.41		
Envelopes and postage	118.25		
Printing	98.85		
		1 520.44	
Treasurer's salary and bond		67.50	
Stationery		86.72	
			$5 973.15
			$7 237.60

Year.	President.	Membership at End of Year.				Annual Convention.		Receipts.	Expenditures.	Cash Balance.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296 86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	*George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	792	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10
1909	Robert J. Thomas	647	55	13	715	New York, N. Y.	Sept. 8–10, '09	5 305.31	†4 566.84	‡3 449.57
1910	George A. King	678	56	13	747	Rochester, N. Y.	Sept. 21–23, '10	6 507.08	†7 237.60	‡2 719.05

* Deceased. † Not including December JOURNAL and reprints. ‡ Does not include $1 815 invested in bonds.

The Secretary, Mr. Willard Kent, submitted the following report:

Report of the Secretary.

Mr. President and Members of the New England Water Works Association, — Your Secretary submits the following report of the general condition of the Association and of changes in the membership for the year ending December 31, 1910.

MEMBERSHIP.

The present membership of the Association is 747; that of one year ago was 715, a gain of 32 during the year.

The detailed statement of the changes in membership during the past year in the several grades is as follows:

MEMBERS.

January 1, 1910.	Total members		647	
	Withdrawals:			
	Resigned	10		
	Died	6		
	Dropped	24	40	
			—	607
	Initiations:			
	January	3		
	February	8		
	March	1		
	April	12		
	June	13		
	September	9		
	November	3		
	December	2	51	
	Two members elected in 1909, but qualified in 1910		2	
			—	53
	Reinstated:			
	Member dropped in 1907	1		
	Members dropped in 1909	2		
	Member resigned in 1909	1		
	Members dropped in 1910	14		18
				— 678

HONORARY MEMBERS.

January 1, 1910.	Honorary members			13

ASSOCIATES.

January 1, 1910.	Total associates		55		
	Withdrawals:				
	Resigned	4			
	Dropped	5	9		
				46	
	Initiations:				
	January	1			
	April	2			
	September	4			
				7	
	Reinstated:				
	Associate resigned in 1905		1		
	Associates dropped in 1910		2	3	56
January 2, 1911.	Total membership				747

DIED.

D. H. Gilderson, superintendent water works, Haverhill, March 14, 1910.
W. J. Goldthwait, Marblehead, Mass., December 7, 1909.
J. W. Goodell, water commissioner, Burlington, Vt., October 9, 1909.
William Jackson, city engineer, Boston, Mass., June 30, 1910.
C. H. Rollins, water commissioner, Watertown, Mass., July 20, 1910.
N. P. Simin, civil engineer, Moscow, Russia, July 17, 1909.

SUMMARY OF RECEIPTS OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR THE YEAR 1910.

Receipts.

Initiation	$275.00
Dues	2 870.00
Advertising	1 736.25
Subscriptions	168.00
JOURNAL	196.50
Lunches	950.00
Reprints	60.42
Specifications	43.55
Sundries	19.74
	$6 319.46

SUMMARY OF DISBURSEMENTS CERTIFIED BY SECRETARY FOR THE YEAR 1910.

On account of JOURNAL	$1 044.02
Stationery and printing	667.55
Assistant Secretary	600.00
Incidental expenses	298.46
Rent	533.33
On account of Editor	150.00
Secretary	200.00
Advertising agent	237.50
June excursion	189.90
On account of stenographer	52.50
Reprints	32.00
Hotel lunches	924.08
Stereopticon	22.00
Badges	51.80
Library	6.75
Insurance	17.50
Total of bills certified by Secretary	$5 027.39
Additional bills paid per Treasurer's report	2 210.21
	$7 237.60

There is due the Association:

Specifications	$2.10
Advertisements	36.25
JOURNAL	1.00
	$39.35

There are no outstanding bills against the Association.

WILLARD KENT, *Secretary*

The Editor, Mr. Richard K. Hale, submitted the following report:

Report of the Editor.

Boston, January 11, 1911.

To the New England Water Works Association, — I present the following report as editor of the Journal of the New England Water Works Association for the year 1910.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year (including the cost of the December Journal and reprints, bills for which were received too late to pay in 1910, and which are consequently not included in the Secretary's and Treasurer's statements); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is considerably larger in total pages and pages of text than that of any preceding year.

Illustrations. — The total cost of illustrations for the year, including printing, has been $127.11, or 3.7 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. There have been no advance copies of papers prepared during the year. The net cost to the Association for reprints and advance copies has been $143.74 (assuming that the December reprints chargeable to members are promptly paid for).

Circulation. — The present circulation of the Journal is:

Members, all grades	747
Subscribers	56
Exchanges	24
Total	827

an increase of 25 over the preceding year.

Advertisements. — The December issue contained 27 pages of paid advertising, which, if maintained throughout the year, would mean an annual income from this source of $1 870. A year ago the figures were 23½ pages and $1 640, showing considerable increase during the year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $43.55 have been sold. Five hundred copies have been printed, at a cost of $27.50, representing a net gain of $16.05 for the year. The net gain up to a year ago had been $191.20, so that the total net gain from this source to date is $207.25. There are still about one hundred and forty-eight copies of specifications on hand, or about $14.80 worth if sold at retail.

The Association has a credit of $0.98 at the Boston Post-office, being the balance of the money deposited for payment of postage upon the Journal at

pound rates. There are no outstanding bills against the Association on account of the JOURNAL, which are not included in these tables.

Respectfully submitted,

RICHARD K. HALE, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XXIV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1910.

Number.	Date.	Pages of									Total Cuts.
		Papers.	Proceedings.	Total Text.	Membership.	Index.	Advertisements.	Cover and Contents.	Inset Plates.	Total.	
5	March	220	38	258	—	–	27	4	1	290	1
2	June	73	13	86	—	–	30	4	2	122	6
3	September . . .	71	3	74	2	–	30	4	9	119	19
4	December . . .	204	21	225	2	8	32	4	6	277	12
	Total . . .	568	75	643	4	8	119	16	18	808	38

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXIV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1910.

Receipts.		*Expenditures.*	
From advertisements . .	$1 750.00	For printing JOURNAL . .	$2 354.71
From sale of JOURNAL . .	204.50	For preparing illustrations,	79.36
From sale of reprints . .	34.25	For editor's salary . . .	300.00
Subscriptions	168.00	For editor's incidentals .	30.70
	$2 156.75	For advertising agent's commissions	250.00
Net cost of JOURNAL . .	1 334.06	For advertising incidentals,	7.25
		For reporting	290.80
		For reprints	177.99
	$3 490.81		$3 490.81

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XVI TO XXIV INCLUSIVE, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XVI. 1902.	Vol. XVII. 1903.	Vol. XVIII. 1904.	Vol. XIX. 1905.	Vol. XX. 1906.	Vol. XXI. 1907.	Vol. XXII. 1908.	Vol. XXIII. 1909.	Vol. XXIV. 1910.
Average edition (copies printed),	1 200	1 200	900	900	900	1 085	1 000	1 000	1 150
Average membership	571	587	596	625	665	693	699	710	732
Circulation at end of year	648*	656*	667	705	767	785	780	802	827
Pages of text	403	430	491	587	495	500	500	459	643
Pages of text per 1 000 members	707	733	824	939	745	722	715	646	880
Total pages, all kinds	584	619	794	784	662	669	681	627	808
Total pages per 1 000 members,	1 020	1 051	1 332	1 254	995	964	976	884	1 090
GROSS COST:									
Total	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61	$3 111.15	$3 490.81
Per page	4.18	4.38	3.69	4.17	3.88	3.95	4.01	4.97	4.32
Per member	4.27	4.61	4.91	5.23	3.87	3.82	3.91	4.39	4.78
Per member per 1 000 pages,	7.32	7.46	6.18	6.67	5.85	5.70	5.88	7.00	5.90
Per member per 1 000 pp. text	10.60	10.72	10.00	8.91	7.81	7.62	8.02	9.56	7.44
NET COST:									
Total	$622.89	$770.62	$648.11	$1 072.95	$387.96	$483.15	$131.06	$789.98	$1 334 06
Per page	1.07	1.25	.82	1.37	.58	.72	.19	1.26	1.65
Per member	1.09	1.31	1.09	1.72	.58	.70	.19	1.11	1.82
Per member per 1 000 pages,	1.87	2.12	1.30	2.20	.88	1.04	.28	1.78	2.25
Per member per 1 000 pp. text	2.71	3.05	2.22	2.93	1.18	1.39	.39	2.43	2.83

* Exclusive of three hundred sample copies.

Report of Auditing Committee.

Boston, January 11, 1911.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers.

While the gross income has shown an increase of some twelve hundred dollars, the expenditures have increased in a still greater ratio, and the assets of the Association show a decrease of about seven hundred dollars.

Respectfully submitted,

JOHN C. CHASE,
GEORGE H. FINNERAN,
Auditing Committee.

On motion of Mr. Stacy, it was voted that the reports of the Secretary, Treasurer, Editor, and Auditing Committee be accepted, placed on file, and printed.

Mr. Charles W. Sherman, chairman, presented a report from the committee "on information as to the conditions under which extensions of water mains are made by town-owned water supplies."

On motion of Mr. Bancroft, it was voted to accept the report and to discharge the committee.

Mr. King, the retiring President, at this point made his annual address.

President's Address.

Members of the New England Water Works Association:

Gentlemen, — At this meeting you expect and are entitled to receive from your officers a record of their stewardship. This has been given you. Reference to a few matters may be pertinent.

Our membership has increased in numbers 32 during the year, — a gain of 1 in the associate list and 31 in the active list. The balance is on the right side, and therefore we may take a hopeful view of the condition; but a gain of 5 per cent. annually is not what it should be. It can be increased only by *individual* effort.

The report of receipts and expenditures shows a draft on our surplus to pay current expenses. The overdraft will be greatly reduced when a balance sheet is struck off after the issue of the December Journal, the cost and receipts for which justly belong in the accounts of 1910.

This association has, during the year, been in conference with other organizations in several important matters.

We were invited to be represented by a delegate in the Boston-1915 Movement, and Vice-President McInness was selected for the position.

The movement for erecting a building for the headquarters of the various scientific and technical societies in Boston received fresh impetus early in the year and, under the leadership of Professor Hollis, representing the Mechanical Engineers, has continued its activities throughout the year. Vice-President Metcalf is our representative on the general committee.

A conference on "Uniform Accounting for Water Works" was held at Washington in May, at which this association was represented by its President. A report was agreed upon which has not been published. The final draft of the report was left in the hands of a committee, and it is understood that they are revising certain technical features. The result of this conference will probably tend to bring the various state authorities to more uniform methods in their demands for accounting by the different works under their jurisdiction.

Delegates were appointed to represent this Association at the Conservation Congress at St. Paul, and their report was given at the annual convention in Rochester.

The success of the special meeting in Hartford in April may be largely attributed to the work of the local members. It was an experiment worthy of repetition.

In one matter I was unable to convince the Executive Committee of the desirability of a change I advocated. Being strongly convinced of the soundness of my position, I wish to make it a matter of record. An organization, with members scattered all over the world, and seven hundred in number, doing a publishing business of $3 000 per year, should, I believe, be incorporated.

I wish to express here my deep appreciation of the loyal, efficient work of the members of the Executive Committee and to acknowledge that to them belongs the credit for any measure of success attained during the year, also to express my thanks to the members of the Association for their many kindnesses.

Early in the year I conceived the idea of collecting data, hoping

at this time I might interest you by giving a glimpse into the field of water-works activities in 1910.

It can be but a glimpse, as time would not permit to give even a list of the places where new systems are being constructed, where radical and extensive changes in old works are being made, where high-pressure fire systems are being planned, where larger pumping plants are being installed, where a revision of rates is being agitated, where a more complete system of metering is demanded, and where purer water through some method of sterilization or filtration is a necessity which is being cared for. The wealth of material makes the labor of eliminating enough to bring this address within the time at our disposal a most difficult task. Only the largest undertakings and those of the best-known localities can be mentioned unless some special feature seems to demand it. The material here presented is from printed articles in engineering and technical literature, and is not given from first-hand information. Conflicting articles have prevented the use of some material. With these general statements let us turn to some of the work going on abroad.

In the early part of the year the Prince of Wales (now King George) turned on the additional sources of water supply which marked the completion of the Vrynwy water scheme for Liverpool and the suburban district of 215 sq. miles outside the city.

The scheme was sanctioned by Parliament in 1880. To carry it out, villages, schools, and churches had to be demolished, and their site submerged some 80 ft. A reservoir was built containing more than 12 thousand million gallons. An aqueduct 68 miles long was constructed, and mountains have been tunneled to bring the water of two other valleys to this reservoir. The total cost has been £3 000 000.

London is just completing a reservoir for storage of water from the river Lea. The reservoir is two thirds of a mile wide and a mile and two-thirds long, and to guard against damage by large waves it is divided into two sections by a wall. The bed of the reservoir is in clay and the sides lined partly with brick and partly with cement. It cost $2 750 000. London has 62 other reservoirs with capacity of 8 913 million gallons which will supply the city 39 days. The new reservoir will add 13 days' supply.

The Metropolitan Water Board of London will ask sanction of Parliament for a scheme to provide a series of reservoirs in the Thames Valley. It will require twenty years for their construction and they will cost $55 000 000.

Works which have cost $20 000 000 were recently opened in Vienna by the Emperor Francis Joseph with impressive ceremonies. The supply is brought 100 miles, from " delicious Alpine springs " at a height of 6 000 ft. above the sea. It requires forty-eight hours for the water to reach the city. Vienna claims it has the best water supply in the world.

In Granada the old system of water supply, which through neglect has long refused to work, has been repaired under Senor Crudaye, an architect, and the famous fountains in the Alhambra are playing again.

Jerusalem, with 80 000 inhabitants, depends almost entirely on rain for water supply, which is about 27 in., and this is stored on roofs in cisterns. Various efforts have been made since King Solomon's time to secure a supply for the city. There are three reservoirs known as Solomon's Pools about seven and one-half miles nearly south of the city, which will hold 3 000 000 gallons of water. These are filled with water from the hills in rainy weather. From these pools a masonry aqueduct built by King Solomon carried water to the temple at Jerusalem; at one point it runs through a mountain in a tunnel. In the sixteenth century this was remodeled by Mohammedans.

In the second century the Romans had an ambitious scheme to bring water through an aqueduct some 20 miles long, but seemed unable to finish it. In 1901, the authorities, aroused by serious shortage, repaired King Solomon's aqueduct, using iron pipe in places. The supply is but a trifle to the city's need. Parliament, in Constantinople, granted the municipality a right to appropriate hides of all animals slaughtered in Jerusalem as a tax to produce a fund with which a water supply could be secured. The city proposes to make a large loan and to repay it by this tax and receipts for water. A Bremen firm has made a proposition, now under consideration by a committee of the city government, to pump Ain Farrah water into Jerusalem, piping each house and charging for same 1.25 francs (about 24 cents) per cubic meter.

To any one paying in advance 1 500 francs, they offer to furnish one cubic meter per day for thirty years. About 75 cu. m. are allowed to the city free and the balance at half price. The whole work is to become the property of the city in thirty years.

An elevated reservoir has been under construction at Calcutta. The city has been supplied by direct pumping. There was difficulty in designing a reservoir as it must rest on the crust of earth not more than 20 ft. thick underlaid by soft silt and must be built to resist earthquakes, although these are not very severe there. The reservoir built is a steel tank 320 ft. square, 16 ft. deep, and raised 90 ft. above the ground on steel columns. The column footings consist of a reinforced concrete bed 340 ft. square and 2.5 ft. thick; in some places short piles were driven. The structure and contents weigh about 70 000 tons, or a pressure of about 1 200 lb. per square foot.

Pekin's 600 000 inhabitants, until the present year, never had a public water supply. Since the foundation of the city in the thirteenth century, they have depended on private wells, which for many years have been fertile sources of disease.

A few months ago a local company of Chinese got together a capital of $2 000 000, and city works were built. Water is obtained from a mountain stream 10 miles northeast of Pekin. It is carried to settling tanks, then filtered through river sand and finally pumped to three city reservoirs with combined capacity of 1 200 000 gal. The daily capacity of the plant is 3 500 000 gal. A curious method of delivery is in use; the water runs from a water tower to 420 street hydrants, each manned by a coolie, where it is retailed at so much per quart or gallon.

Twenty progressive consumers have had pipes carried directly to their premises, where meters are installed. The rate is 20 cents per 1 000 gal. The company is now endeavoring to popularize bathing, to increase the trade in water.

An increased supply of water for Honolulu has been obtained by the building of the largest dam on the island at a cost of $300 000. The new dam, which is known as the Nuaun, will impound enough water for many months' supply for the city.

At the celebration of the Mexican Centennial of Independence on September 21, in the presence of a large gathering of officials

and guests, a new water system for Mexico City was inaugurated.

An additional supply for Vancouver, B. C., was necessitated by the rapid increase of population. Water will be taken from Seymour Creek, 7 miles above its mouth, at an elevation of 465 ft. above the sea. The pipe line has four and one-third miles of 30-in. and 36-in. wood stave pipe and the rest is made of lap welded steel pipe. A distribution reservoir of 24 000 000 gal. capacity will be built at an elevation of 395 ft. above the sea. The bottom and side slopes are to be of concrete.

The Pacific coast of our country has been the scene of unusual activity in water-works matters. The Los Angeles project, probably exceeded in magnitude by only one other in the world, has been pushed and is now nearing completion. Little of the work is done by contract but is done by the men employed directly by the city. Early in the year a delay was occasioned by a failure in the furnishing of money by the sale of the bonds, and nearly the entire force was laid off for a time.

We get but a faint idea of the magnitude of this scheme when we are told that 240 miles of aqueduct are to be built at a cost of $24 500 000, and that an estimate of the quantity to be obtained is 260 million gallons per day. Some of the items help us in our attempt to conceive its vastness. Five thousand men have been employed upon the work this year, 80 000 acres of land have been bought, 500 buildings have been erected, 240 miles of telephone and 230 miles of road constructed. A cement mill has been equipped, capable of turning out 1 000 barrels per day. The Southern Pacific has a contract to convey 20 000 000 ton-miles. The courage and confidence in their future is manifest in the vote of the city endorsing the scheme, which was virtually to tax themselves $88 per capita. The vote stood 21 918 in favor and only 2 128 against the project.

San Francisco, on January 14, 1910, voted on two propositions for a water supply which would lead to a change from private to municipal ownership of system. The vote was by a large majority in favor of the Hetch Hetchy project. The permission granted the city for the use of this valley by former Secretary of Interior Garfield has been suspended and final decision postponed until

May 1, 1911. Meantime measures looking to a compromise so that the city may buy the Spring Valley Water Company property are under consideration.

A proposition of the People's Water Company to sell its entire holdings to the city of Oakland, Cal., for $18 500 000 has been before the city council of that city. The district served by this company includes Oakland, Berkeley, Alameda, Richmond, Pinola, San Pablo, San Leandro, and several smaller towns. The above proposition has stirred to vigorous action a rival company, the Bay Cities' Water Company. Fifty canvassers have been at work for the latter company, and the people are said to be signing contracts for the water by the thousands, and the water problem for the east side of San Francisco Bay is said to be solved.

At Seattle, Wash., improvements are in construction, with others in contemplation. Seattle expects to secure as large a supply of pure water as Los Angeles at about one third the cost.

At Portland, Ore., a third water main under the Willamette River is about to be laid which will increase the city's supply by 50 000 000 gal. per day, at a cost of $125 000.

The question of a municipal supply for Denver, Colo., is agitating that city. The Denver Union Water Company ask $14 400 000, the appraised value, for their plant which the public utilities commission says is worth but $6 405 000. The voting taxpayers have refused a renewal of the franchise of the company. A suit has been filed in the interest of the company in the United States District Court asking an injunction to restrain the city from holding an election to authorize an $8 000 000 bond issue for the construction of new works.

After eight years of litigation, Omaha, Neb., has voted to buy the works of the Omaha Water Company at the valuation of the appraisers. Its vote has been sustained by the court, and the company must accept the amount of the appraisal, $6 263 295, although the company's stock and bonds represent $11 750 000.

Work upon the intake tunnel for the Buffalo Water Works, begun some three years ago, has continued and is nearing completion. This tunnel is about 11 000 ft. long. Buffalo has spent upwards of $3 000 000 in the improvement of the works.

Baltimore, Md., has adopted a plan of improving her water

supply at an estimated cost of $6 630 000. A new reservoir is to be built in Gunpowder Valley. Coagulating and settling basins will be built and used with sand filtration.

The biggest water-works scheme in the world is that under construction for Greater New York. This project was organized in 1905, but construction work was not begun until February, 1908. Briefly, the project is to impound water in the valleys near the Catskill Mountains and bring it about 92 miles to New York at a cost of $162 000 000. It is expected the supply will be 500 million gallons per day. The impounding dam, known as the Olive Bridge dam, is being built and is said to be second in size in the world. It will impound 127 thousand million gallons. About one half of the work on this project is now under contract. The Ashokan Reservoir on the Esopus Creek is now under construction. It will be 12 miles long and one to two miles wide.

In this scheme there are 35.4 miles of pressure tunnels and 13.8 of gradient tunnels. Work is in progress upon several of these tunnels. At one of them, the Wallkill, the contractors have established a hospital to accommodate 18 patients and employ a resident surgeon. There are said to be 11 000 men at work upon the whole scheme and 270 policemen are employed for the protection of persons and property.

In connection with this scheme a deep rock pressure tunnel for the distribution of the water to various parts of Greater New York has been adopted. This tunnel, as planned, will be 17.5 miles long and 200 ft. below the surface of the street. It will cost from $25 000 000 to $50 000 000. Contracts are about to be executed for this work.

We would belie our name if no New England work was mentioned. Pittsfield, Mass., has authorized an extension of the system of suppy to cost $500 000. A stone and concrete dam will be built to store 440 000 000 gal.

Springfield, Mass., early in the year began to use the water of their new supply taken from the Little River in Westfield.

Portland, Me., is rebuilding its works. The contract has been let for laying 14 miles of main. The cost will be nearly $1 000 000. The contractor is said to be using machinery in excavating for the pipe trenches.

Power and Pumps.

We note almost innumerable instances of pumping plants undergoing changes and having additions made to them. Frequent mention is made of gas-producer plants, gas engines, and electric-driven pumps. The latter is not confined to the smaller pumps, twelve million gal. daily are pumped with electric pumps in Duluth and one of 20 000 000 gal. capacity is recommended for Minneapolis. Gas-producer plants have been rapidly increasing in number and in amount of power produced. During 1909, their power was nearly doubled and the number of plants increased 70 per cent. The same increase for 1910 is probable. The steam turbine is being widely used.

An engine advocated as a valuable auxiliary of the steam turbine is the rotary. Several working models of these engines have attracted considerable attention during the year, and their inventors claim that they have perfected a practical engine. For more than one hundred and twenty-five years inventors have attempted to build a successful engine of this type and it is said that Westinghouse has spent three quarters of a million dollars in the endeavor to produce one. Tests have recently been made with rotary engines of 20 h.p. to 25 h.p. with gratifying results. Whether engines of large horse-power of this type can be built, remains to be developed. Some of the advantages claimed for this type are the small space they occupy and the small amount of vibration as well as economy of power.

Tanks.

Reinforced concrete is being more and more used in building tanks and standpipes. The pictures of those being built emphasize the variety of forms which this material allows. We find the plain round tank whose bottom is on the ground and which has an open top and the tank on concrete pillars 112 ft. high which has a concrete roof. Concrete reservoirs, both open and covered, are being built all over the country. The Southern Pacific Railroad are building tanks to hold 60 000 gal. These have a bottom supported by a dome built of reinforced concrete.

At Syracuse, a handsome standpipe of steel with an outside

protecting wall of vitrified brick and artificial stone has been built.

High-Pressure Systems.

An emergency high-pressure service has been put in operation at Jacksonville, Ga. It has five miles of mains from 8 in. to 20 in. in diameter. It uses electric motor driven pumps.

Oakland, Cal., has completed a salt-water fire protection system giving a pressure of 150 lb. per square inch at hose nozzles. The part of the system now built encircles seventy blocks in the business district.

The high-pressure fire main service has been extended in the northeast or mill section of Philadelphia. The mains are from 10 in. to 20 in. in diameter and there will be 300 lb. working pressure when in service. This system is claimed to be the most complete and powerful fire-fighting apparatus in the world. It is estimated to cost $2 000 000.

Camden, N. J., has authorized the issuing of bonds to the amount of $400 000 for an auxiliary water plant for fire and commercial purposes.

Cleveland, Ohio, is considering the installation of a high-pressure pumping station. High-pressure mains have already been laid which are supplied with water by tug boats. Toledo, Ohio, Joliet and Bloomington, Ill., are considering the installation of high-pressure mains for fire protection, and extensive additions are being demanded in Boston, Mass.

Six hundred thousand dollars is being spent in Baltimore, Md., for a high-pressure fire system capable of supplying 29 000 gal. per minute. It is designed so as to take its supply either from the city's mains or from the river, the latter to be used in an emergency. The mains are lap welded, soft, open hearth, steel pipe. It is usually laid in 20-ft. lengths, although one piece of 10-in. pipe 117 ft. long has been laid.

Electrolysis.

Troubles from electrolysis have not been reported during the year to any great extent.

It is reported that in Houston, Tex., large mains in the business section have been replaced as they have been destroyed by the

underground currents of electricity. Mention is made of similar trouble at Elyria, Ohio, and Tusla, Okla.

A suit for an injunction to prevent the Central Railway Company of Peoria, Ill., injuring by electric currents the property of the Peoria Water Works Company, has been tried and the verdict rendered. The master's report indicated a complete victory for the water company. The master's report was not sustained by Judge Sanborn of the United States Circuit Court. The decision of the judge, while in a way a compromise, seems to favor the street railway rather than the water company.

Meters.

It is reported that in one of our large cities where meters are being extensively installed some large increases have been noticed in water bills. Two cases are cited, in each of which an annual flat rate charge of $16.50 had been collected. After metering, in one case the charge for three months was $57.60, and in the other for the same period $96. One real estate owner was so indignant over the increase that she ordered the water shut off and the buildings torn down.

The desirability of installing meters is being considered in a large majority of the municipally owned works not now metered.

Scranton people are happy in the fact that they have not suffered from shortage of water, and attribute it to the saving occasioned by the use of meters. A suit in this city to recover for a bill for metered water was contested on the ground that the bill was too large and that the meter was "working double." The water company proved the accuracy of its meter and obtained a verdict in its favor.

At Houston, Tex., a reduction in rates of 50 per cent., and the probability of another reduction soon, is attributed to the use of meters.

The largest claim noted of the benefit to be obtained from the use of meters is the reported statement of a prominent engineer to one of our large cities that the water consumption would be decreased 100 per cent. by the use of meters. It is a fair statement that meters "protect the innocent, punish the offender, lessen the cost of operating the plant, and conserve the water supply."

Rates.

A spirit of unrest seems to prevail all over the country in regard to proper rates for use of water. The methods employed to determine rates are varied and some are unique. The tendency, as stated, is very general toward meterage. For metered water, prices have been quoted during the year from two to forty cents per thousand gallons. Hydrant rentals paid private companies are from $2.50 per hydrant, in San Francisco, to $65 for the first 100 hydrants and $50 for the balance, in Vicksburg, Miss. With the advent of total meterage will come more scientific methods of determining rates. The decisions of the Wisconsin Railroad Commission, which is practically a public utility commission, and the methods used by it, are forerunners of what may soon prevail in all the states. Its decision in the case of the Ripon Light and Water Company is worthy of study.

Collection of Rates.

We note that in two instances the plan of shutting off the supply of delinquents has been forbidden by boards of health on sanitary grounds.

Waukegan, Ill., water department will post the names of delinquents of two years' standing.

Consumption.

The conditions in different places vary so largely that without full knowledge we cannot make fair comparisons. We notice two cities claiming the largest consumption in the United States: Ann Arbor, Mich., with the amount not given; and Spokane, Wash., with a consumption of 289 gal. per capita per day. The latter claim also to be furnishing water cheaper than any city in the United States.

The consumption of Buffalo, N. Y., is reported as 300 gal. per day.

Care of Watershed.

When asked if the water of certain springs was pure, an old negro replied, "Yessum. Dis yar water has been scandalized by de best phrunologers in de lan', and dey say, dey do, as how it

muntain ten parts er oxhide acid, ten parts er cowbonic acid, and de balance am clar hydrophobia — Yessum." To secure this pure water is one of the great problems of the day.

More and more attention is being paid to the sanitary conditions of the watersheds. On many of them inspectors are constantly patrolling, and on some, land purchases are being made. We notice Newark, N. J., has paid $52 000 for one tract of 328 acres, and $12 000 for another of 600 acres. We note that a judge has refused the application of a party desiring to keep a hotel on this watershed. Improvements on the watershed of the supply of Mt. Vernon, N. Y., are demanded. North Adams, Mass., has appropriated $20 000 for purchasing land on the watershed of its supply. Rochester, N. Y., has procured about all the land about Lake Canadice. Atlantic City has expended more than $350 000 in securing the watershed of its supply and has purchased over 6 000 acres. In many instances, the care of the watershed is insufficient and some means of treating the water becomes necessary.

Filtration.

The old method of sand filtration is still being installed, even outside of Massachusetts. It is frequently supplemented by some chemical as coagulant or sterilizer being introduced prior to the filtration. This method is proposed for Baltimore. Sixteen sand filters are in process of construction for Reading, Pa. Niagara Falls, N. Y., will use sand filters to filter 15 000 000 gal. per day. Sand filters are under construction for Toronto whose daily capacity will be 35 000 000 gal.

Hypochlorite of lime is being much used in water sterilization. Omaha, Neb., began its use early in 1910 and is sterilizing 27 000-000 gal. daily. It is about to be tried if not already in use in Kansas City, Mo.; Milwaukee, Wis.; Bridgeport, Conn.; and for part of the Croton supply for New York.

Mechanical filtration is being installed in many places, among them is Bangor, Me.; Atlanta, Ga.; Rock Island, Ill.; and Montreal, Quebec. Newport, R. I., has just completed a plant. Whether or not this system will be installed in Lynn, Mass., is still undecided.

Ozone.

The use of ozone for water sterilization still continues. It seems to be successfully used in France. At Nice they have completed two plants with a total capacity of 10 000 000 gal. per day and have another under construction. As the ozone is produced by electricity, the process is frequently mentioned as an electric treatment. The failure of this treatment at Lindsay, Ont., seems to have been due to the fact that the ozone and water were not properly mingled, and not from failure to produce ozone. An experiment at Ogdensburg, N. Y., failed to remove the color of the water.

An ozone sterilization plant for treating daily 10 000 000 gal. filtered water from the River Marne (a highly polluted stream) is under consideration for Paris. It is said the cost of treatment has been $6.67 per 1 000 000 gal.

Ultra-Violet Rays.

Some very interesting laboratory experiments with ultra-violet rays from a quartz-tube mercury arc lamp have been made in Paris. The use of these rays for such purposes has been known since 1877, but only recently has their use been attempted for disinfection of water in any large quantities. These experiments show that their use begins to look feasible. About a year ago, the city of Marseilles opened a competition to various mechanical filtration concerns. At the end of the tests, the city proposed to decide which method it would adopt for purification of its water supply. Each company was required to install, at its own expense, a plant of sufficient size to purify 52 840 gal. of water every twenty-four hours. As a result of this test, the ultra-violet ray system, with a preliminary treatment through roughing filters, was accepted. In the apparatus used, the water was required to pass the lamp three times. The cost of sterilization was about $10 per million gallons, and in 8 tests where an aggregate of 1 700 B. coli per liter were found before treatment, none were found after, and 98.3 per cent. of other bacilli were removed. Cleveland, Ohio, is considering a trial of this method.

Filtration plants at Wilmington, N. C.; Grand Rapids, Mich.;

and Minneapolis, Minn., are under construction, and Toledo, Ohio, has but recently put one in operation. The plant at Wilmington, Del., is stated to be the " most up-to-date filtration plant in the world."

At the city of Farlington, England, the Portsmouth Water Company have a slow sand filtration plant in which the filters are in part located on top of the storage reservoir.

It may not be out of place to here mention that the Supreme Court of Minnesota has just handed down a decision in which it holds that municipalities in that state are liable in damage suits for the death of citizens who contract disease through drinking polluted city water.

Several large claims have been in litigation for alleged unlawful taking of water. A decision in the case against the American Sugar Refining Company for stealing water at its Williamsburg plant has been rendered by Judge O'Brien, the referee. He awarded the city $525 000 and costs.

The National Lead and Oil Company is accused of taking water to the value of $60 000 from the Water Company at Parnassus, Pa. Suit has been entered to recover the above, with damages set at $100 000.

In Philadelphia, the high-pressure mains have been unlawfully tapped and one property owner has settled for $3 000.

Accidents.

It would seem to the writer that in the past year there had been an unusually large number of breaks in big mains, and breaks that have done serious damage.

The breakage of a five-foot main threw 3 000 men out of work and did property damage to amount of $75 000, beside cutting off a town's supply for several days.

The breaking of a main in one city threw paving blocks as high as the house tops, and another city lost 8 500 000 gal. of water. In another city the breaking of the water main broke the gas main and filled it with water and sand.

Asheville, N. C., had its supply main crushed by the fall of a big tree. Akron, Ohio, had a strange accident befall its works.

By the breaking of a brick sewer, the sewer was plugged and the sewage overflowed from a manhole, ran down a hill a distance of more than one fourth of a mile, and flooded Summit Lake, the city's source of supply. The lake had to be drained.

Corona, Cal., has had its water supply materially increased as the result of an earthquake.

Among the water items noted are, — that the divining rod and hydroscope are still used in searches for water supplies; that the women of Saginaw, Mich., to the number of 1 657, registered to vote upon the question of issuing bonds to the amount of $400 000, to build a water and filtration plant for the city.

An unusual memorial is a system of water works, but the town of Thornton, Ind., has the distinction of having one.

The entire system was the gift of Gen. Anson Mills, in memory of his father and mother. Water is raised from a 110-ft. well by an air-lift system, and delivered to a 20 000-gal. underground concrete reservoir. A turbine centrifugal pump raises it to a steel 40 000-gal. tower, 80 ft. high. The machinery is operated by electricity.

We have spoken of the large number of places in which construction has been in process in 1910. In the ordinary course of affairs, one would naturally expect greater activity the coming year. The great drought which has prevailed over such a large extent of our country is likely to cause an unusual amount of engineering and constructing work in 1911.

Let me close with this sentiment for the New England Water Works Association in 1911, —

May it be the best year it has ever known, and the worst it will ever know.

Election of Officers.

Mr. Charles W. Sherman submitted the following report of the tellers appointed to canvass ballots.

President.

Allen Hazen	316	Scattering	4

Vice-Presidents.

J. Waldo Smith	286	Morris Knowles	197
Leonard Metcalf	286	Ermon M. Peck	147
Michael F. Collins	278	George H. Snell	107
Irving S. Wood	273	Samuel P. Senior	78
Frank A. McInness	261		

Secretary.

Willard Kent 324

Treasurer.

L. M. Bancroft 320

Editor.

Richard K. Hale 327

Advertising Agent.

R. J. Thomas	327	Scattering	1

Additional Members of Executive Committee.

Edwin A. Fisher	293	William E. Maybury	266
John J. Kirkpatrick	287	Oren E. Parks	119

Finance Committee.

A. L. Sawyer	311	John H. Walsh	247
George H. Finneran	285	William E. Maybury	109

The President thereupon declared the following-named gentlemen to have been elected officers for the ensuing year: President, Allen Hazen; Vice-Presidents, J. Waldo Smith, Leonard Metcalf, M. F. Collins, F. A. McInness, I. S. Wood, and Morris Knowles; Secretary, Willard Kent; Treasurer, L. M. Bancroft; Editor, R. K. Hale; Advertising Agent, R. J. Thomas; additional members of the Executive Committee, W. E. Maybury, E. A. Fisher, J. J. Kirkpatrick; Finance Committee, G. H. Finneran, A. L. Sawyer, and J. H. Walsh. He then presented Mr. Hazen, who spoke as follows:

Gentlemen, Fellow-Members of the New England Water Works Association: I feel very deeply the honor that you have conferred

upon me. I feel it more deeply because I believe that I am the first non-resident member who has ever been elected to this proud office. I looked yesterday through the list of my illustrious predecessors, twenty-eight of them, one for each year of the Association's work. They have been and are representative men, leaders, men who have led the Association in its work to some purpose, and I am proud to have my name added to the list.

I began my professional work in Boston. My shingle was hung out at 85 Water Street, where our editor now holds out. The work went well during those first two years in partnership with Mr. Noyes, who was elected President of this Association twenty years ago. It went well largely because of the wide acquaintance which Mr. Noyes had, and the universal respect and esteem in which he was held. Afterwards, finding myself alone in the world, and having found out something of the character of the New England Water Works men, I saw that they were too far along in the game to be fooled very long. [*Laughter.*] I knew it would only be a matter of a short time when they would find out how little I really knew about water works. [*Laughter.*] So I looked around for some place where the game was easier, and I moved to New York. [*Laughter.*] Fifteen years afterward, I have only kind words to say of New York, but I want to say to you that I appreciate, more than I can tell, the many, many times that I have been called back to the home field to help you in your problems, and I appreciate very much indeed what you have done for me to-day in conferring upon me the great honor that you can give. [*Applause.*]

Mr. Chase. Mr. President, I do not think it is ordinarily the thing to thank an official for doing his duty, but when he goes beyond it, I think there should be some notice taken of it. I think, therefore, that the thanks of this Association are due to the retiring President for the very able, exhaustive, and instructive address he has given us on the water-works engineering conditions in the country and in the world in the past year, and I move that our thanks be tendered to him for his address. [*Applause.*]

The motion was put by Mr. Hazen and was enthusiastically carried.

Adjourned

FEBRUARY MEETING.

HOTEL BRUNSWICK,
BOSTON, February 8, 1911.

The President, Allen Hazen, in the chair.
The following members and guests were present:

HONORARY MEMBER.

Frederic P. Stearns.

MEMBERS.

S. A. Agnew, Kenneth Allen, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, F. D. Berry, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, E. C. Brooks, G. A. P. Bucknam, James Burnie, G. A. Carpenter, J. C. Chase, R. D. Chase, M. F. Collins, E. D. Eldridge, A. N. French, A. D. Fuller, F. L. Fuller, Albert S. Glover, J. M. Goodell, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, L. M. Hastings, Allen Hazen, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, J. J. Kirkpatrick, Morris Knowles, E. E. Lochridge, H. P. T. Matte, N. A. McMillen, A. E. Martin, H. A. Miller, F. L. Northrop, E. M. Peck, T. A. Peirce, Henry Roberts, A. L. Sawyer, W. H. Sears, J. E. Sheldon, J. Waldo Smith, W. F. Sullivan, C. N. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. L. Tighe, E. J. Titcomb, J. A. Tilden, W. H. Vaughn, G. E. Winslow, H. B. Wood. — 60.

ASSOCIATES.

Anderson Coupling Company, by C. E. Pratt; Builders Iron Foundry Company, by A. B. Coulters and George H. Lewis; Chapman Valve Manufacturing Company, by H. L. Dewolfe; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; The Fairbanks Company, by W. D. Cashin; Platt Iron Works Company, by F. H. Hayes; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden and W. A. Hersey; Henry R. Worthington, by E. F. Nye; Lead Lined Iron Pipe Company, by T. W. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, H. L. Weston, and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Valve Company, by F. S. Bates; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle. — 24.

GUESTS.

G. H. Abbott, treasurer Water Company, Southbridge, Mass.; I. S. Holbrook, *Engineering Record*, Clarence Goldsmith, E. T. Jonson, New York City; George W. Bowers, Lowell, Mass.; Anthony Flemming, John D. Hanachan, J. J. Desmond, Lawrence, Mass.; Frank Collins, White River Junction, Vt.; E. W. Priest, J. W. Mackenzie, Mansfield, Mass.; and C. E. Batchelder, Boston, Mass. — 12.

THE PRESIDENT. It is my sad duty to announce the death of one of our members, Professor Kinnicutt. He had been a member of the Association for some eighteen years, and was a man whom we have all known and loved, a man of great unselfishness, always working for the benefit of those about him and for the cause. The Association has suffered a great loss in his death.

The Secretary then presented applications for membership from the following-named persons, all properly recommended, and approved by the Executive Committee: Joseph N. McKernan, Plainville Conn., member Plainville Water Board; Clarence Goldsmith, New York City, hydraulic engineer, National Board of Fire Underwriters; C. Nelson Harrub, Mundale, Mass., resident engineer in charge of the West Parish Filter Plant, Springfield, Mass.; C. H. Abbott, Southbridge, Mass., superintendent and treasurer, Southbridge Water Supply Company; George W. Priest (for associate membership), Mansfield, Mass., president of New Hartford Water Company and of the Composite Pipe Company.

On motion of Mr. Frank L. Fuller, the Secretary was instructed to cast the ballot of the Association in favor of the applicants above named, and he having done so, they were declared elected members.

The President then presented Mr. J. Waldo Smith, chief engineer, who, the program announced, would read a paper on "Construction Work on the Water Supply of New York City." "The New York water supply construction now under way," said the President, "is, I suppose, the largest piece of waterworks construction that has ever been carried out. Certainly that is true of all modern times, and is true, so far as quantities are concerned, even if we go back to the old Roman days, although the Roman aqueducts certainly meant as much to mankind, if

not more than anything undertaken at this time. The work is not only very large, being second only to the Panama Canal work as an engineering enterprise, but it is being prosecuted rapidly and well."

Mr. Smith said he had no paper to present, but had merely come over from New York to show a few pictures and to explain what was being done to furnish an addition to the present supply of the city of New York. He proceeded to give an informal talk illustrated by a large number of stereopticon views.

Mr. Kenneth Allen, chief engineer of the Metropolitan Sewerage Commission, New York, read a paper on "The Use of the Salinometer in Studies of Sewage Disposal by Dilution."

Adjourned.

March Meeting.

Hotel Brunswick,
Boston, Wednesday, March 8.

Vice-President M. F. Collins in the chair.

The following members and guests were present:

Honorary.

Frederic P. Stearns.

Members.

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GUESTS.

F. W. Dinwiddie, water registrar, Gardner, Mass.; Frank F. Connor, Lowell, Mass.; J. P. Wood, Marlboro, Mass.; Edward Parrish, Asst. U. S. Engineer, Newport, R. I.; John Currier and H. B. Andrews, Boston, Mass.; J. J. Desmond, Lawrence, Mass.; Albert S. Benson, Wm. L. Sharpe, East Greenwich, R. I.; Nathaniel T. Kidder, Milton, Mass.; Edward F. Hughes, Watertown, Mass.; Randolph Bainbridge, Quincy, Mass.; Irving T. Guild, F. W. Rane, and Edward S. Bryant, Mass. Forestry Association, Boston. — 15.

The chairman, on behalf of the Executive Committee, announced that the April meeting would be held at Springfield, Mass. The papers will be on fire protection, both from the point of view of water-works men and practical fire fighters.

The Secretary presented applications for membership from the following, properly endorsed by the Executive Committee:

Active membership: Edwin D. Pingree, Providence, R. I., vice-president and engineer for Manufacturers Mutual Fire Insurance Company; E. P. Stone, Saginaw, Mich., engaged in contracting and dredging work; Boris N. Simin, Moscow, Russia, designer and constructor of water works; J. W. Ledoux, Swarthmore, Pa., water supply, water power, and general hydraulic engineer, and chief engineer for American Pipe and Construction Company; J. L. Van Ornum, St. Louis, Mo., consulting engineer in various sanitary plans in Missouri, and expert in Chicago Drainage Canal cases; Hiram B. Andrews, concrete reservoir and standpipe construction engineer; Rudolph Bainbridge,

Wollaston, Mass., commissioner of public works for the city of Quincy; H. M. Urban, Birmingham, Ala., chief civil engineer, Tennessee Coal, Iron and Railroad Company, in charge of water-works construction and water supply improvement; William L. Wilcox, assistant chief civil engineer, Tennessee Coal, Iron and Railroad Company.

The Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared elected.

The first paper of the afternoon was on "The New England Portion of the Proposed Atlantic Intra-Coastal Waterways," by Edward Parrish, assistant United States engineer, Newport, R. I., illustrated by stereopticon views. The subject was discussed by Mr. T. G. Harard, Jr., Mr. Frank L. Fuller, and Mr. A. S. Negus.

Mr. F. W. Rane, state forester of Massachusetts, then presented a paper, which was illustrated by stereopticon views, on "The Reforestation of Watersheds for Domestic Supplies." The paper was discussed by E. R. B. Allardice, superintendent of the Wachusett Department, Metropolitan Water Works; E. S. Bryant, practical forester, Boston; Mr. Nathaniel F. Kidder, president of the Massachusetts Forestry Association; Mr. William F. Sullivan, engineer and superintendent, Nashua, N. H.; and Mr. Irving T. Guild, secretary of the Massachusetts Forestry Association.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association, at the rooms of the Association, 715 Tremont Temple, Boston, Mass., Wednesday, January 11, 1911.

Present: President George A. King, and members Allen Hazen, Ermon M. Peck, Michael F. Collins, George A. Stacy, George W. Batchelder, Edwin C. Brooks, Willard Kent, Lewis M. Bancroft, Richard K. Hale, and Robert J. Thomas.

Two applications were received and recommended for admission, namely:

For membership: Henry E. Warren, chairman water commissioners, Ashland, Mass., and A. Lincoln Fellows, consulting engineer, Denver, Colo.

A communication from the local agent of Henry R. Worthington with reference to transfer of associate membership from the International Steam Pump Company was presented, and the Secretary was instructed to communicate with the International Steam Pump Company with reference to same.

The Platt Iron Works Company, having complied with the requirements of the constitution, was, by unanimous vote, reinstated as an Associate.

The committee on annual meeting and the committee on the library submitted their reports and, on motion of Mr. Stacy, the subject of both reports was referred to the next Executive Committee.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., February 8, 1911.

Present: President Allen Hazen, and members J. Waldo Smith, Michael F. Collins, Morris Knowles, John J. Kirkpatrick, Richard K. Hale, Robert J. Thomas, and Willard Kent.

A communication from the secretary of "Boston 1915" was read, and Mr. Frank McInnes was made a committee of the New England Water Works Association to represent that Association at the conference of the "1915" organization.

On motion of Mr. J. Waldo Smith, it was *voted:* That, provided suitable arrangements can be made, Gloucester, Mass., be selected as the place for holding the next annual convention.

On motion of Mr. Morris Knowles, it was *voted:* That the President be, and hereby is, authorized to appoint a committee to arrange for the annual convention of 1911, with full powers, fixing the convention as near as may be to the second Wednesday of September.

Mr. Richard K. Hale was made a committee on the June outing, with power to appoint two associates. Messrs. G. A. King and W. E. Maybury were subsequently appointed.

A communication was received from Mr. C. E. Chandler with reference to statistics of Rainfall and Run-off, and on motion of Mr. Hale it was *voted:* That the President be, and hereby is, authorized to appoint a suitable committee to investigate the yields of New England watersheds, and such other watersheds as the committee may deem desirable, during the present dry period.

The President subsequently appointed Messrs. F. P. Stearns, H. K. Barrows, C. E. Chandler, X. H. Goodnough, R. A. Hale, E. E. Lockridge, Leonard Metcalf, A. T. Safford, and J. L. Tighe.

Five applications for membership were received and recommended for admission, namely:

For membership: Mr. C. Nelson Harrub, superintendent filter plant, city of Springfield, Mass., Westfield, Mass.; G. H. Abbott, treasurer Southbridge Water Supply Company, Southbridge, Mass.; Clarence Goldsmith, hydraulic engineer, Commissioner on Fire Protection, National Board of Fire Underwriters, New York City; Joseph N. McKernan, member water board, Plainville, Conn.

For associate membership: George W. Priest, Mansfield, Mass.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Wednesday, March 8, 1911, at 11.30 A.M.

Present: Michael F. Collins, William E. Maybury, John J. Kirkpatrick, Robert J. Thomas, Richard K. Hale, Lewis M. Bancroft, and Willard Kent.

Nine applications were received and recommended for admission, namely:

For membership: Edwin D. Pingree, engineer Manufacturers Mutual Fire Insurance Company, Providence, R. I.; E. P. Ston, president Water Board, Saginaw, Mich.; B. N. Simin, engineer, Moscow, Russia; J. W. Ledoux, hydraulic engineer, Philadelphia, Pa.; J. L. Van Ornum, professor civil engineering, Washington University, St. Louis, Mo.; H. B. Andrews, civil engineer, Boston, Mass.; Randolph Bainbridge, commissioner of public works, Quincy, Mass.; H. M. Urban, chief civil engineer, T. C. I. & R. R. Co., Birmingham, Ala.; Wm. L. Wilcox, assistant chief civil engineer, Tennessee Coal, Iron and Railway Company, Central Water Works, Birmingham, Ala.

Mr. George W. Priest, president and manager of the New Hartford Water Company, was transferred from associate to active membership in the Association, by motion of Mr. Thomas.

On motion of Mr. Kirkpatrick, seconded by Mr. Bancroft, it was voted to hold a special meeting of the Association on the second Wednesday in April.

On motion of Mr. Bancroft, seconded by Mr. Hale, it was voted that the April special meeting be held in the city of Springfield, Mass., and that the President, Secretary, Mr. E. E. Lochridge, J. J. Kirkpatrick, and A. E. Martin, be a committee of arrangements, and that the subject for discussion be "Fire Protection."

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARIES.

Louis E. Hawes died from apoplexy, at Wakefield, on January 29, 1911. Mr. Hawes was born in Springfield, Mass., on January 27, 1860. On graduating from the Worcester Polytechnic Institute in 1882, he became assistant superintendent of the Water Works at Northboro. In 1883, he was made assistant engineer on the construction of the Wakefield Water Works, and in 1892, he designed the sewerage system for that town, and became chairman of the sewerage commission in 1895.

Mr. Hawes has been prominent in the construction of water works throughout New England for the past thirty years. Among the works built under his direction are those at North Attleboro, Norwood, Ayer, Edgartown, Provincetown, Marion, Needham, Avon, Mass., Rockland, Me., Dover, N. H., and many others.

Mr. Hawes was married in Wakefield in 1886 to Hattie M. Emerson, who, with a son and daughter, survives him.

Mr. Hawes was a member of the American Society of Civil Engineers and of the Boston Society of Civil Engineers. He was elected a member of the New England Water Works Association on December 12, 1888.

Leonard Parker Kinnicutt* was born in Worcester, Mass., May 22, 1854, the son of Francis H. and Elizabeth Waldo (Parker) Kinnicutt. After graduation from the Massachusetts Institute of Technology in 1875, as bachelor of science in the department of chemistry, he spent four years at the universities of Bonn and Heidelberg, studying under the famous chemists, Bunsen and Kekule, and coming into contact with Hempel

* Memoir prepared by Leonard Metcalf.

of Dresden, Treadwell of Zurich, Anschutz of Bonn, and other well-known scientists, with whom he kept up a lifelong correspondence. Returning to the United States he studied for a year at Johns Hopkins University, under Remsen, and was then called to Harvard College as instructor in chemistry. For three years he taught there, incidentally taking the degree of doctor of science himself, and was then called to Worcester. There he spent the rest of his professional life, first as instructor, 1882, then as assistant professor, 1883, and thereafter as full professor,— being made director of the laboratory in 1892. He died of tuberculosis, February 6, 1911.

During the last twenty years or more of his life Dr. Kinnicutt devoted much time to problems in sanitary science, upon which subject he became a recognized authority. Frequent trips to England and the Continent, coupled with his keen interest in science and his winsome personality, kept him thoroughly in touch with modern tendencies and developments, and enabled him to perform a unique service alike to science, to the public, and to his fellowmen.

An indomitable worker, he found time to take an active part in matters of civic importance within his field, such as the experimental work in sewage disposal carried on by the city of Worcester, problems touching the city's water and milk supplies, courses of lectures for foremen and skilled mechanics, and many other questions of lesser importance.

The files of many professional journals and papers and the many quotations from his utterances bear witness to the activity of his mind and pen, while the attention and interest with which men listened to him bore witness to the soundness of his views. His last work upon "Sewage Disposal," written in collaboration with Winslow and Pratt, is the latest and best book of its kind upon this subject.

He was a Fellow of the American Association for the Advancement of Science, and member of many societies and clubs, — the American Chemical Society, New England Water Works Association (of which he was elected a member on February 8, 1893), Boston Society of Civil Engineers, Society of Bacteriology, the London and German Chemical societies, Association

of Managers of Sewage Disposal Works of England, and of the Worcester, St. Botolph, Bohemian, Harvard, and Tatnuck Country clubs.

In his college work Dr. Kinnicutt was most successful. His knowledge of his subject and enthusiasm as a teacher commanded the respect and attention of his students, but it was his knowledge of men, his real and helpful interest in his "boys," both as undergraduates and later as workers and men of the world, that won their loyal support and warm affection. It was to him, of all the faculty, that they turned, whether in need or trouble, or bubbling over with enthusiasm of new discovery or success.

Devoted to his family and his friends, his books and his garden, he was at his best in his home. Keen in his interests and judgment of men, catholic in spirit and taste, he was a rare host, and an addition to any group of men. A fearless yet courteous critic; of good poise and mental balance; a man of the world, yet always human; a lover of mankind,— he was worthy of the love men bore him.

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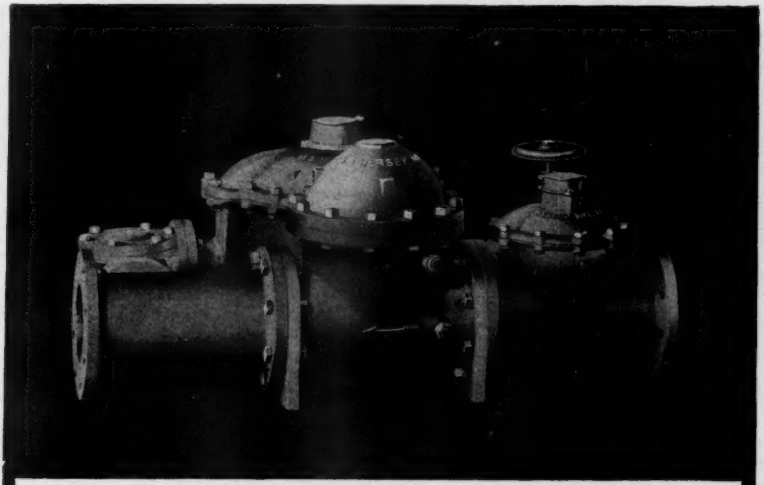

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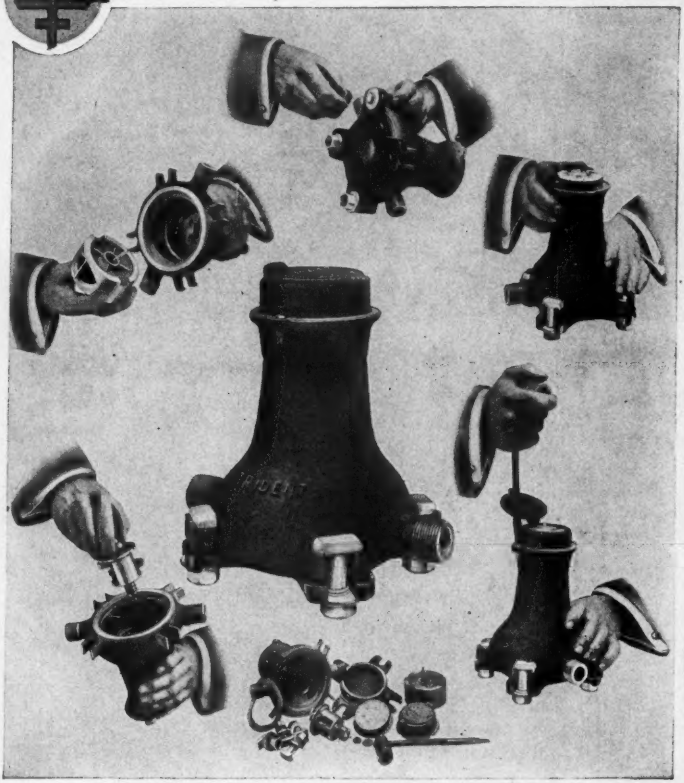

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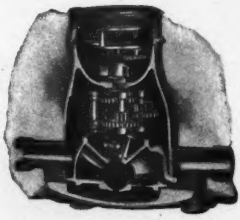

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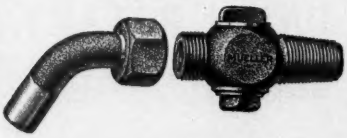

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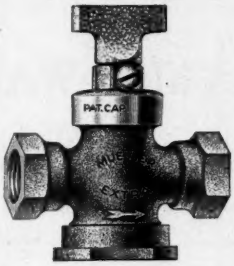

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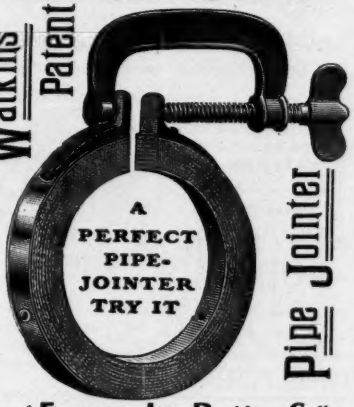

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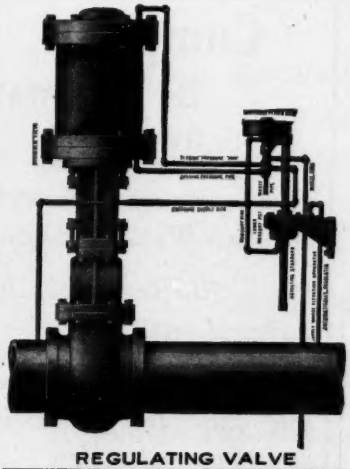

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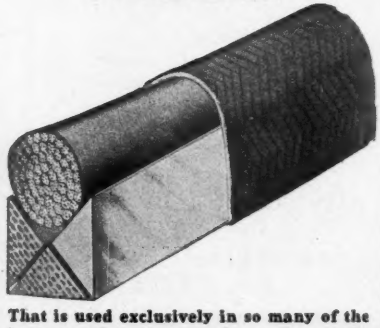

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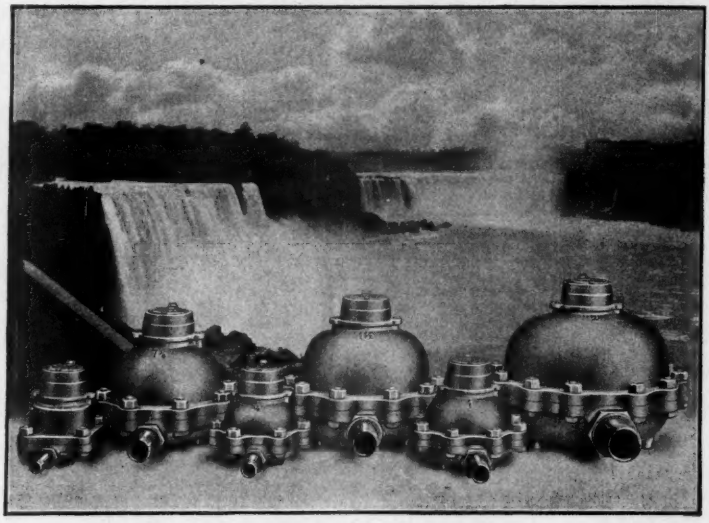

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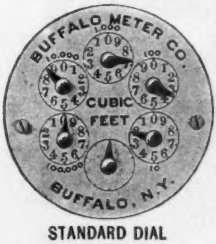

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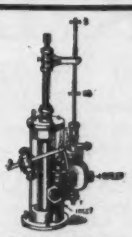

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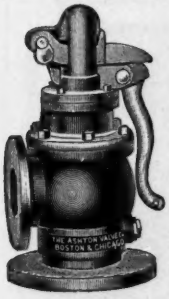

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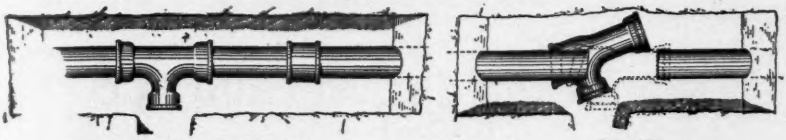

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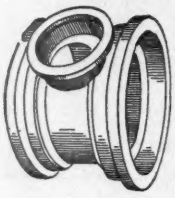

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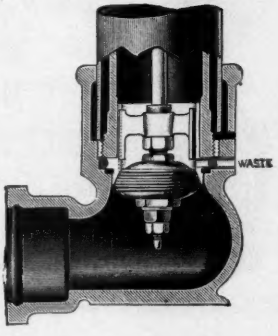

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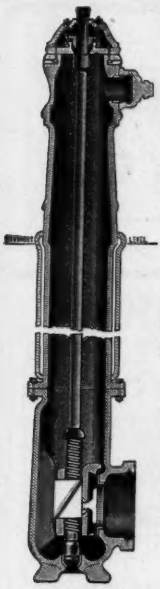

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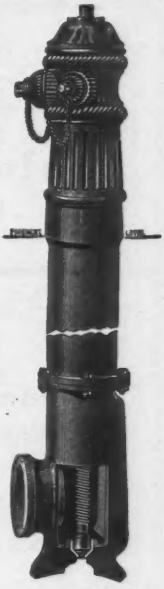

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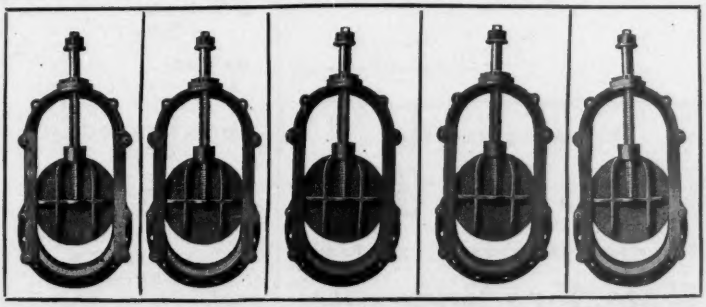

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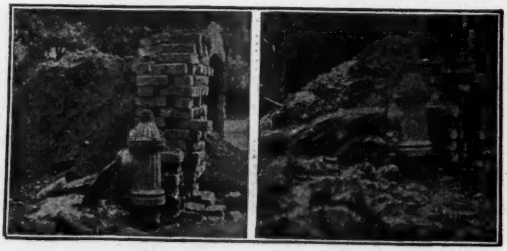

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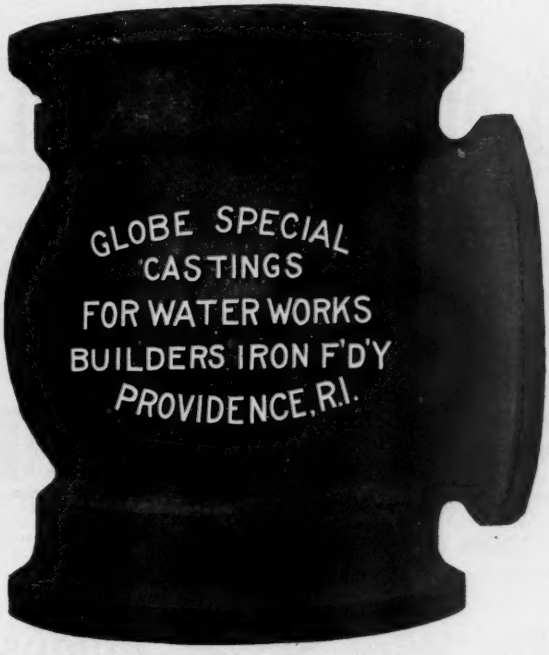

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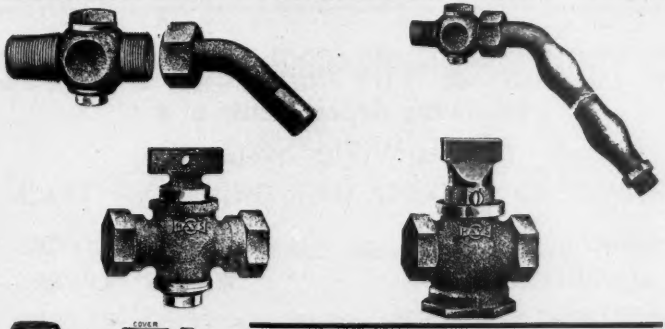

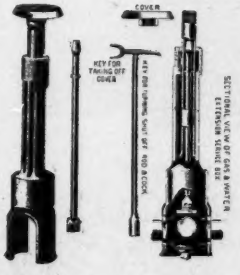

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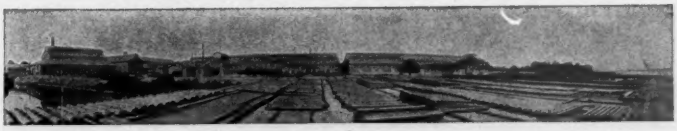

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